VOLUME II

CARPENTER

JOINER

THE MODERN CARPENTER AND JOINER

THE MODERN CARPENTER AND JOINER

BY

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AND
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WITH
SPECIAL SECTIONS ON
THE USE OF THE STEEL SQUARE
BY
HAROLD RYDER

VOLUME II

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THE MODERN CARPENTER AND JOINER

CHAPTER I

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Definitions—Classification—Wall Plates and Joists—Notching—Cogging—Templates—Hangers and Anchors—Corbels—Computing Sizes—Table of Scantlings—Maximum Spans—Common Bridging Joists—Ceiling Joists—Trimming and Trimming Joists—Tusk Tenon—Housing—Strutting—Pugging—Types of Floors : Single ; Double : Framed—Combination Floors : Steel and Wood—Steel Beams—Spring Floors—Valtor Floors—Mill Construction—Flitched Beams—Trussed Beams—Floor Boards and Flooring—Joints—Square or Plain Joint—Rebated—Grooved and Tongued—Rebated, Tongued and Grooved—Filleted—Rebated and Filleted—Ploughed and Tongued—Splayed, Grooved and Tongued—Dowelled Joints—Points in Construction—Sizes for Timbers.

A FLOOR may be defined as the lower horizontal boundary of a room ; the underside of the same structure often being the ceiling of the room or rooms below. It consists of a bridging from wall to wall, or wall to beam, or wall to partition, and affords support to any weights which may be placed thereon. Described in general terms, a floor may be said to be composed of two main parts ; i.e. (1) the bridging structure ; (2) the floor covering.

As has been said of walls, so too floors may be divided into those which form part and are necessary to the rigidity of the whole structure, and those which are independent of the structure and without which the structure would stand, and could, if necessary, be applied after the outside structure is complete.

The bridging structure consists of single joists, double joists, joists and beams or joists and trussed girders, and the floor covering may be either single boarding, double boarding or solid wood blocks upon an under flooring.

CLASSIFICATION

Wooden floors may be divided into three main classifications, i.e.

1. Single.
2. Double.
3. Framed (under which comes Mill Construction).

In all the above classes the same terms will be found to apply. Consequently this further description is prefaced by the definition of all

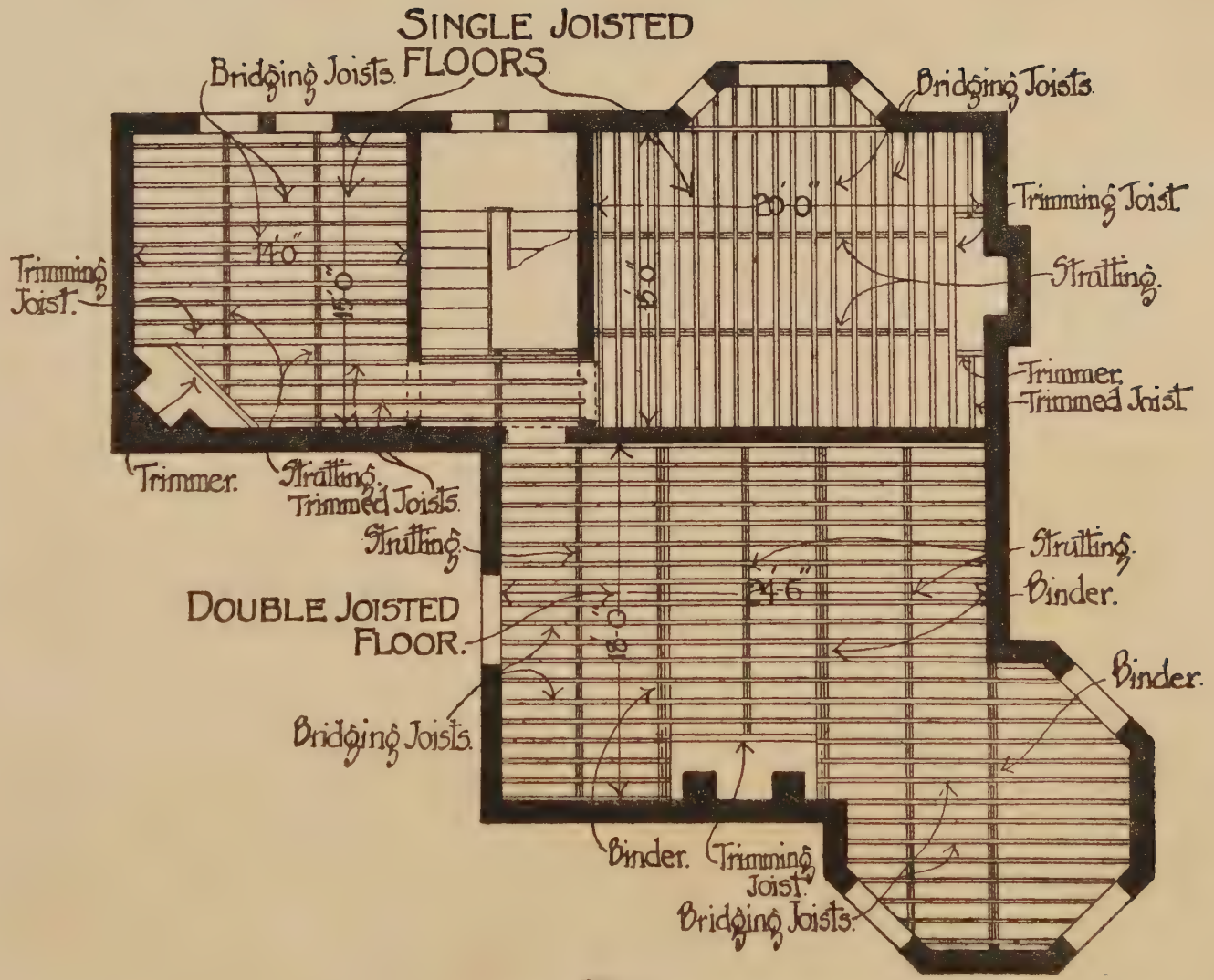

SINGLE JOISTED FLOORS
Bridging Joists.
Bridging Joists.
Trimming Joist.
Strutting.
Trimmer.
Trimmed Joist.
Trimming Joist.
14'0"
20'0"
Trimmer.
Strutting.
Trimmed Joists.
Strutting.
Strutting.
Binder.
DOUBLE JOISTED FLOOR.
24'6"
Binder.
Bridging Joists.
Binder.
Trimming Joist.
Bridging Joists.

Fig. 8.

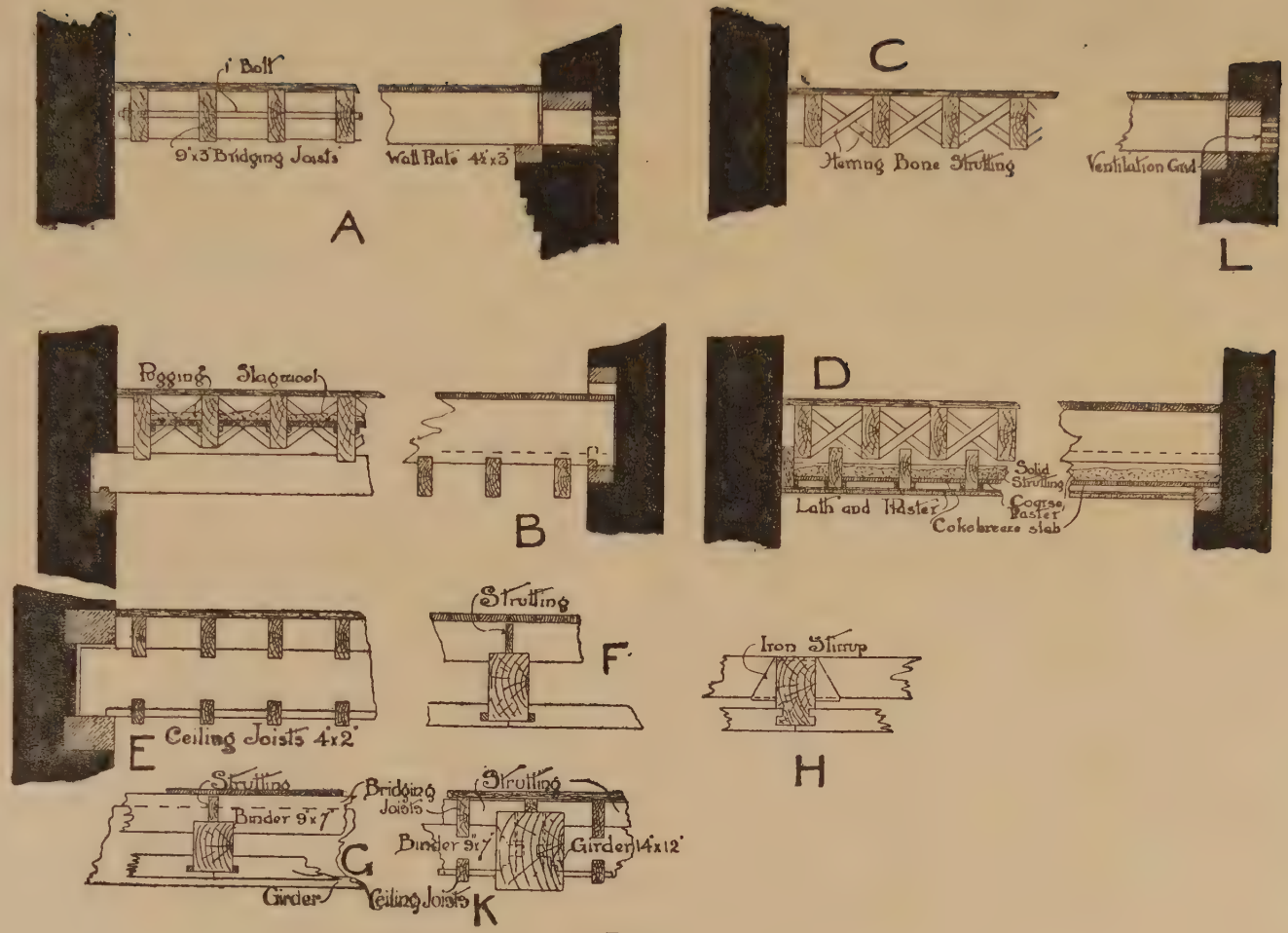
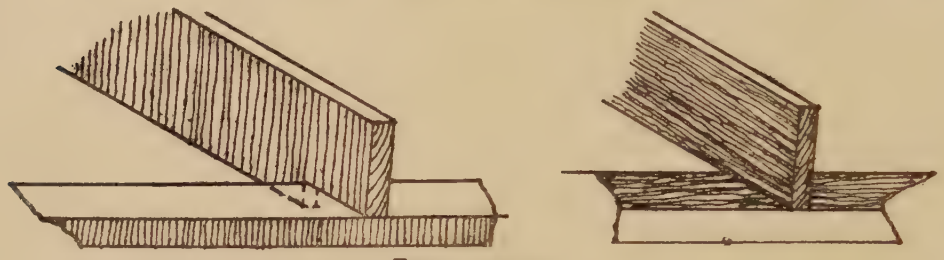

Bolt
9"x3" Bridging Joists
Wall Plate 4"x3"
A
C
Herring Bone Strutting
Ventilation Grid
L
Pugging Slagwool
B
D
Solid Strutting
Lath and Plaster
Coarse Plaster
Cokebreeze slab
Strutting
F
Iron Stirrup
H
E
Ceiling Joists 4"x2"
Strutting
Bridging Joists
Strutting
Binder 9"x7"
Binder 9"x7"
Girder 14"x12"
G
Girder
Ceiling Joists
K

FIG. 3.

parts and the joints used in their construction. These should be read in conjunction with the plan on p. 2, which shows a floor of each class.

Definitions of Parts and Joints Used

Wall Plate and Joists.—The most elementary type of floor bridging



Figs. 4 and 5.

consists of timbers placed on edge and stretching from wall to wall, where they rest upon wall plates at their ends. In order to achieve rigidity, the joists must bear a definite relation in their proportions to the length of their span. This will be found described in detail on p. 6.

Joists.—The joists consist of either plain bridging joists which may also be the ceiling joists of the room below ; *trimmers* which bind any opening cut in the floor for staircases, traps or chimneys to pass through and on which the end of the joists which have been cut rests ; or *trimming joists*, being the bridging joist forming the other boundaries of the opening and on which the trimming joists rest. As will be evident, these two last, the trimmer and trimming joist carrying the additional weight of the joists let into them, must be of larger dimensions than the ordinary bridging joists.

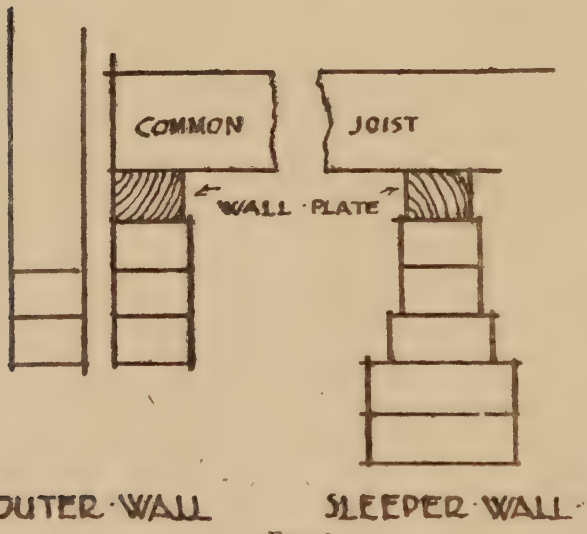


Fig. 6.

Wall Plates.—In fixing and in order to secure a more distributed bearing for the weight of the floor joists, wall plates are run along the walls supporting them. These plates are jointed in their lengths, and at their angles in the manner described on p. 42 under "Roofs."

The joints between the bridging joists and wall plates consist of the following :

A PLAIN JOINT with uncut joists resting on the wall plate and nailed thereto through the side of the joist as in Figs. 4 and 5.

NOTCHING is fully described on pp. 59 and 60, under "Roofing"; also double and dovetail notching.

COGGING, also termed *caulking*, which is similar to the bridle joint already described in that a strip or *cog* is left upon the wall plate, the portions on either side being cut away. The joist has a strip cut out of it at right angles to its length to fit over the cog. In such positions as where it is impossible to project the joist past the wall plate, the cog may be left on the inner edge of the top of the wall plate.

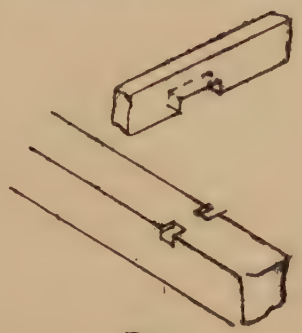


FIG. 7.

TEMPLATES.—In fireproof or partially fireproof buildings the wooden wall plates are replaced by stone templates, but the method renders the fixing of the ends of the wall plates difficult. The templates should be at least 3′ 0″ in length, to aid in distributing the weight of the floor over regular area of wall. Where rigidity of fixing is particularly desired, metal dowels may be let into the underside of the joist and the upper side of the stone template.

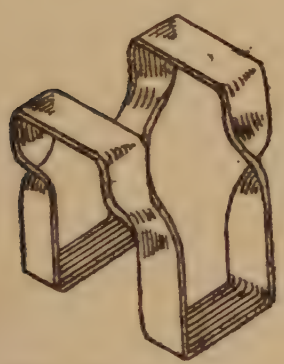


FIG. 8.

HANGERS AND ANCHORS.—In semi-fireproof buildings an effort is made to secure that though the floor joists and beams may be burned, they may be free to fall without injuring the walls. To this end the top corner of the beam is rounded to permit of falling and the underside is *anchored*. To save cutting in the walls and for the same purpose as last described, *hangers* of the type shown in Figs. 8 and 9 are built into the walls and project out to carry the end of the beam. Their use also effects a saving in the length of the beam. For girders of 12″ by 14″ and upward this type of hanger is recommended.

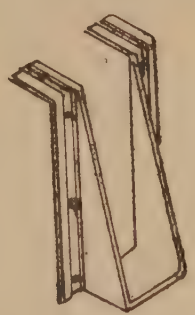


FIG. 9.

CORBELS.—In place of templates, stone corbels may be bracketed out to take the ends of the beams, so that a wall plate is sometimes run from corbel to corbel and the beam cogged thereto. This practice has the additional advantage of permitting a free circulation of air around the timbers and so preventing dry-rot due to lack of air circulation.

SIZES OF WALL PLATES.—Tredgold's rule for computing the size of wall plates is as follows :

For a bearing of 20′ 0″ size = $4\frac{1}{2}$″ by 3″
„ „ 30′ 0″ „ = 6″ by 4″
„ „ 40′ 0″ „ = $7\frac{1}{2}$″ by 5″

SIZES OF JOISTS.—A rule-of-thumb method for computing the size of joists for any given span is as follows. Divide the span in feet by 2 and add 2, which gives the result in inches.

For a more exact calculation, the following table, based on Tredgold's tables, will be found useful.

TABLES OF SCANTLINGS OF GIRDERS, BINDING JOISTS AND CEILING JOISTS OF DIFFERENT BEARINGS, FROM 10′ 0″ TO 30′ 0″

Length of bearing.	Girders. 10′ 0″ centre to centre, 9″ to 12″ bearing on walls.		Binders. 6′ 0″ centre to centre, 4′ 6″ bearing on walls.		Joists. 1′ 0″ centre to centre.		Ceiling Joists. 1′ 0″ centre to centre.	
	Depth.	Breadth.	Depth.	Breadth.	Depth.	Breadth.	Depth.	Breadth.
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
6	—	—	6	4	6	2	$3\frac{1}{2}$	2
8	—	—	7	$4\frac{1}{2}$	7	$2\frac{1}{2}$	4	$2\frac{1}{2}$
10	9	7	8	5	$7\frac{1}{2}$	$2\frac{1}{2}$	5	$2\frac{1}{2}$
12	10	8	9	$5\frac{1}{2}$	8	$2\frac{1}{2}$	6	$2\frac{1}{2}$
14	11	9	10	6	9	$2\frac{1}{2}$	—	—
16	12	10	11	$6\frac{1}{2}$	$10\frac{1}{2}$	$2\frac{1}{2}$	—	—
18	12	11	12	7	12	$2\frac{1}{2}$	—	—
20	13	11	13	$7\frac{1}{2}$	12	3	—	—
22	14	12	—	—	—	—	—	—
24	15	12	—	—	—	—	—	—
26	16	12	—	—	—	—	—	—
28	16	13	—	—	—	—	—	—
30	16	14	—	—	—	—	—	—

TREDGOLD'S FORMULA FOR COMPUTING SIZES OF FLOOR TIMBERS

Bridging joists, 12″ centre to centre: $D = \sqrt{\frac{L^2}{B}} \times 2{\cdot}2$ for fir; or 2·3 for oak.

Binders 6′ 0″ apart:
$D = \sqrt[3]{\frac{L^2}{B}} \times 3{\cdot}42$ for fir; or 3·53 for oak.
$B = \frac{L^2}{D^3} \times 40$ for fir; or 44 for oak.

Girders 10′ 0″ apart:
$D = \sqrt[3]{\frac{L^2}{B}} \times 4{\cdot}2$ for fir; or 4·34 for oak.
$B = \frac{L^2}{D^3} \times 74$ for fir; or 82 for oak.

Ceiling joists, 12″ centre to centre: $D = \frac{L}{\sqrt{B}} \times 0{\cdot}64$ for fir; or 0·67 for oak.

Where D = Depth in inches.
B = Breadth in inches.
L = Span in feet.

COMMON BRIDGING JOISTS.—These, as has been said, are laid from wall to wall and form the only support in single floors. They are spaced

at from 12″ to 14″ from centre to centre of joists ; and should be doubled under all partitions wholly or in part resting on the floor. In ordinary work these joists also carry the ceiling of the room under, the latter being nailed directly thereto. But where it is desired to prevent the

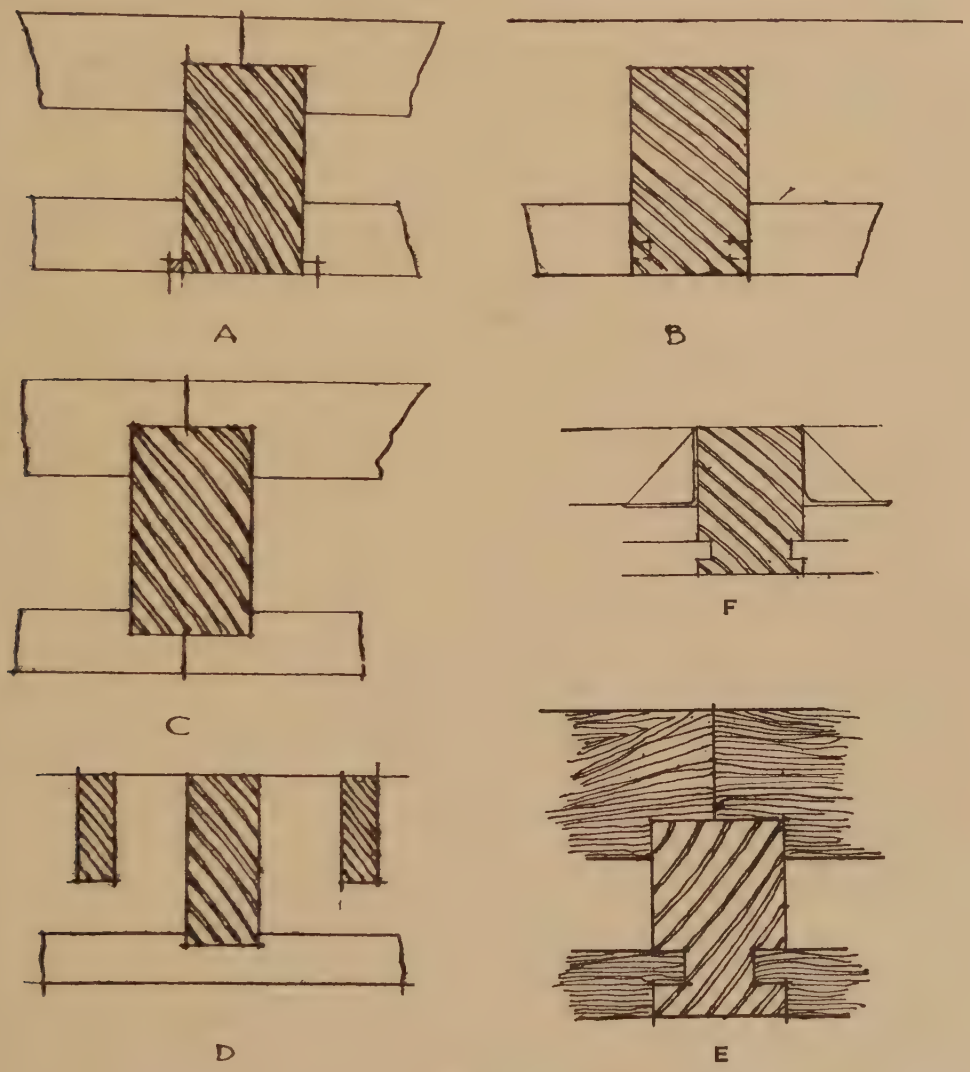


Fig. 10.

percolation of sound as much as may be possible with a single floor, one joist in every five is of deeper dimensions and special ceiling joists of lighter scantlings are nailed thereto. This practice also results in a firmer ceiling, less affected by vibration in the room above, and, of course, in a stronger floor.

Ceiling Joists are spaced at 12″ to 15″, and are mortised as shown in Fig. 10A, or alternatively as in Fig. 10C, which methods have the additional advantage of weakening the binders as little as may be. Ceiling joists are made from 2″ to 2½″ wide and 3½″ deep for a span of 6′ 0″, ½″ being added for every additional foot of span. Ceiling joists may also be let into plain chases cut in the underside of every floor joist and run

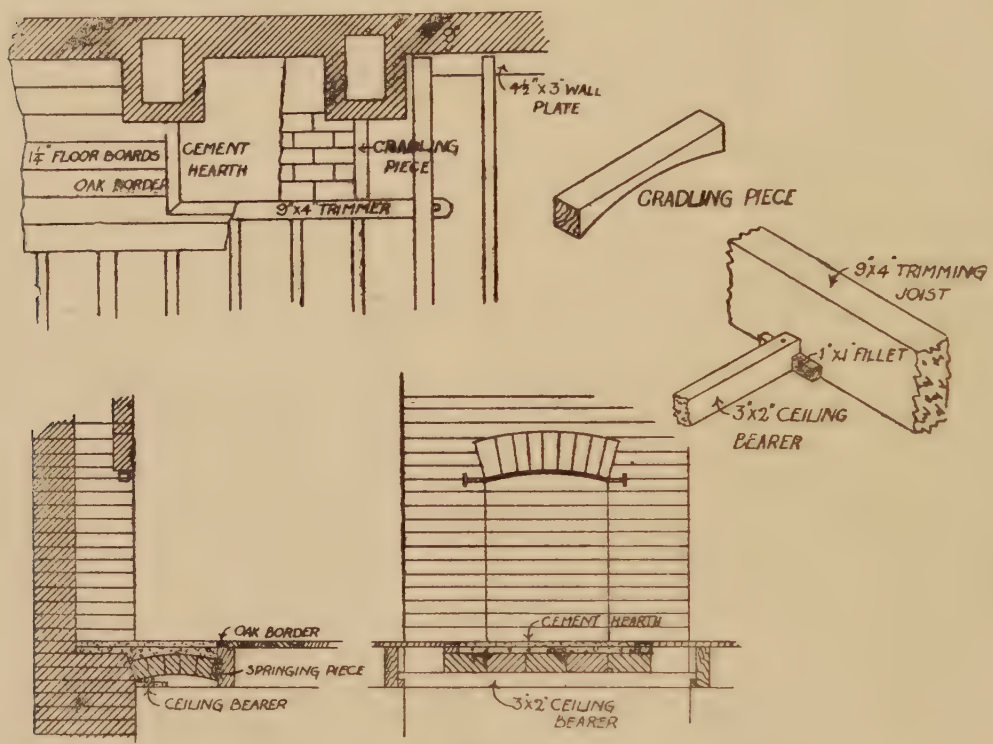


Fig. 11.

at right angles to the floor joists, but the practice is not recommended, owing to the weakening effect upon the floor joists.

Trimming

It will be obvious that the floor joists cannot be continuous from wall to wall in all parts of the building. Openings in the floors will be required for traps, staircase wells and chimneys. When this is necessary, the joists have to be cut and bearers, to take their ends, inserted. The operation is known as *trimming*. The bearers inserted are termed *trimmers*, and the strengthened common joists, on which the ends of the trimmers rest, are known as *trimming joists*. This arrangement varies, of course, in accordance with the relation of the opening to the direction of the common joists. If these are at right angles to the

opening, the common joists are cut at the required distance, and a trimmer is inserted parallel to the opening to carry their ends, as shown in Fig. 13.

Whereas if the length of the opening is parallel to the common joists, the common joist forming the boundary of the long side of the opening is strengthened and becomes the *trimming joist*. Whilst short lengths forming the narrow ends of the opening carry the trimmed common joists and become the *trimmers*, as indicated in Fig. 14.

It frequently happens that triangular and irregular openings have to be cut in floors for angle fireplaces and traps, in which case a *trimmer* is either run across the whole distance of the angle and the common joists trimmed into it ; or a common joist at the requisite distance from the chimney breast is strengthened and becomes the *trimming joist*, and into this the trimmer is mortised.

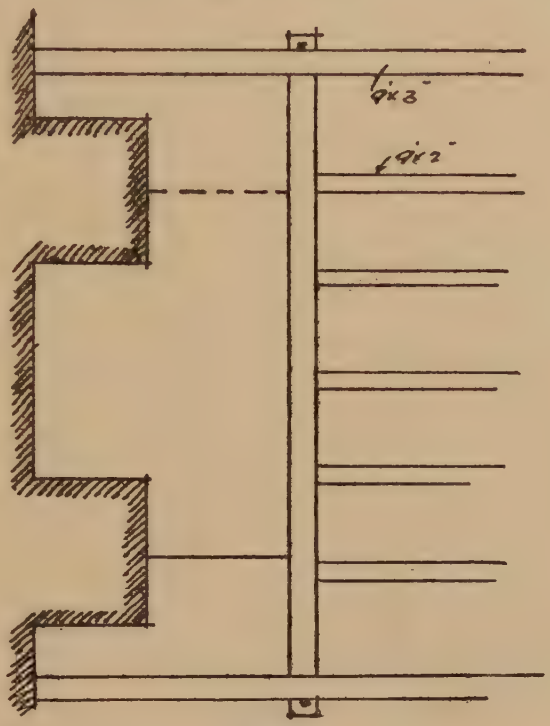


FIG. 12.

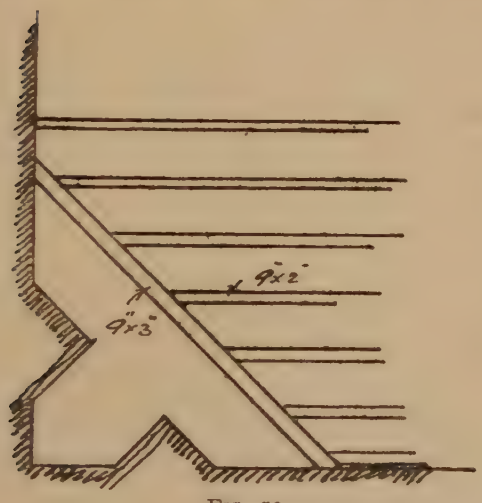


FIG. 13.

TREDGOLD'S RULE FOR COMPUTING THE ADDITIONAL SIZES FOR TRIMMERS AND TRIMMING JOISTS.—To the width of the common joists add $\frac{1}{8}$" for every joist carried by the trimmer, and that will give the width of the trimming joists (see table, p. 6).

DISTANCE OF TRIMMING JOISTS FROM FLUES.—The proximity of wood to flues is determined by the London Building Act, upon which most local building bye-laws are based. This states that no timber in any wall shall be placed nearer than 12" to the inside of any flue or chimney opening, or within 2" from the outer face of any chimney or flue which is less than $8\frac{1}{2}$" thick,

unless the face is rendered. Woodwork under any chimney opening must not be placed nearer than 10″ from the upper surface of the hearth.

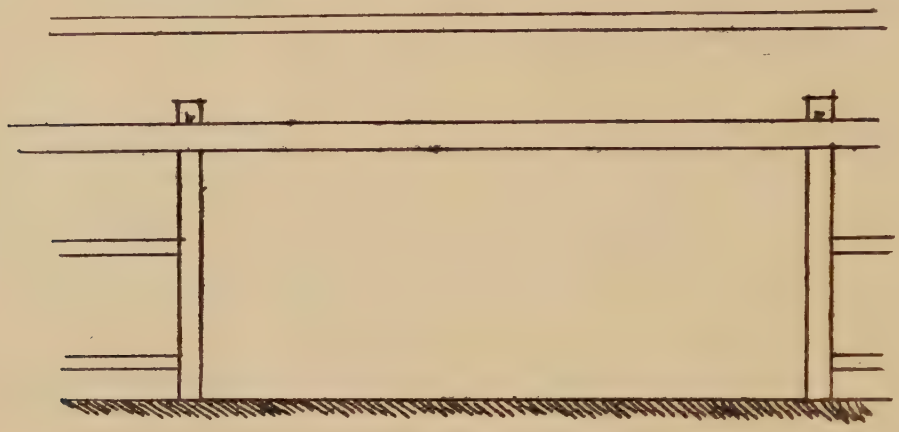


Fig. 14.

Trimmers in Staircase Wells.—These become the bearers on which the *strings* and carriages of the stairs rest, and are then frequently doubled as is detailed later under "Stairs."

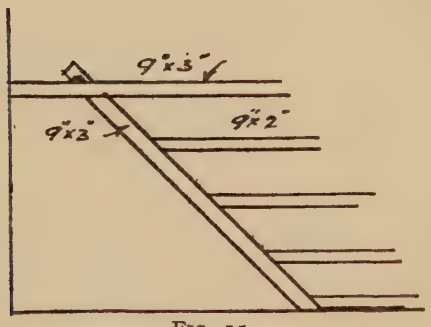


Fig. 15.

Trimming for Bays.—When joists run into bays, they may either be trimmed into trimmers as for openings or they may rest upon beams or binders placed across the length of the opening.

Method of Jointing Trimmers, Trimming Joists and Common Joists.—The common joists may be simply dovetailed and housed into the trimmers as has been already described, or they may be tenoned as shown in Fig. 16, where, to prevent loosening, the tenon is shown wedged with a wedge on either side.

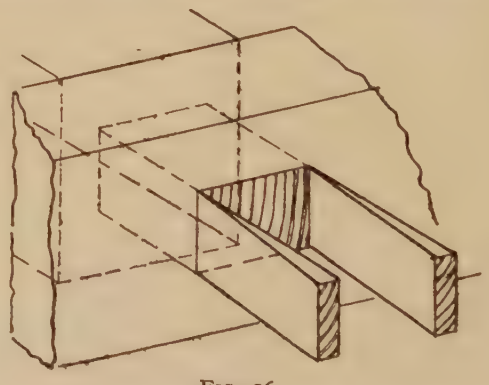


Fig. 16.

Where it is desired to fasten the tenon into the mortise which cannot be cut through the entire width of the larger timber, the mortise is cut wider at the back than the front, and several small wedges are driven into the end of the tenon so far only that they are left projecting from the tenon. The timber with the tenon is then driven endwise into the mortised timber, and the wedges

being thus forced into the tenon cause it to expand and fill the wedge-shaped mortise. This practice is known as *fox wedging*, and is particularly suitable for jointing common joists to trimmers, also for jointing common joists into any timber which has one side against a wall or other obstruction.

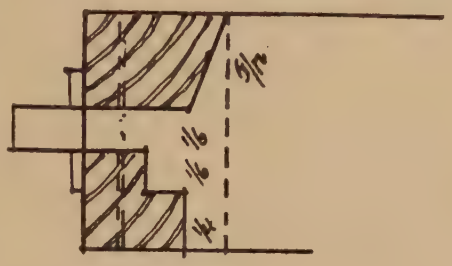


Fig. 17.

Jointing between Trimmers and Trimming Joists

Tusk Tenon.—The *trimmer* is jointed to the *trimming joists* by means of a joint termed the *tusk tenon*. This consists of a tenon cut on the end of the trimmer and projected through the trimming joist, in which position it is wedged. Also to strengthen the bearing on account of the downward thrust due to the weight of the floor and not to place too much strain on the tenon, a horizontal *shoulder* is also cut on the end of the trimming joist under the tenon, the vertical portion left above the shoulder and below the tenon being known as the *tusk*. To reduce the amount which is cut away from the trimmer, that portion of tenon and the top of the tenon upwards. After the end of the trimming joist between the joist is cut on a bevel sloping away from the joists have been fitted together a wedge is driven through the projecting tenon to pull the joint together. The *shoulder* should penetrate the trimmer to a depth equal to one-sixth of the depth of the joist.

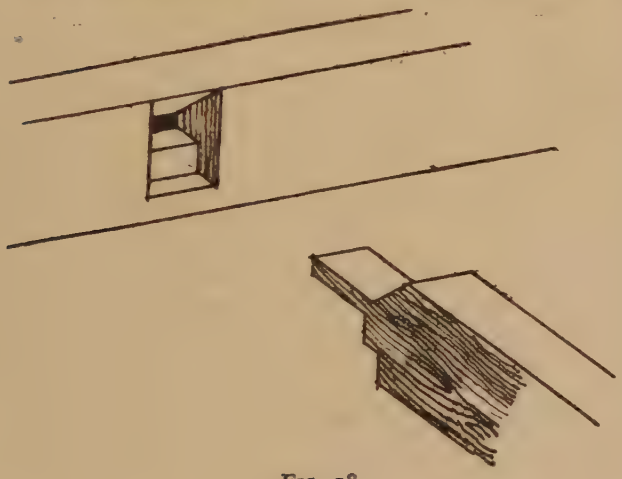


Fig. 18.

Where the trimmer is in the nature of a girder or beam, and of a thickness too great to allow of cutting for the tenon through its entire width, the cut is made so that the tenon penetrates to a distance equal to twice its own depth. It is then pinned from the top of the girder or beam, as is shown in Fig. 19.

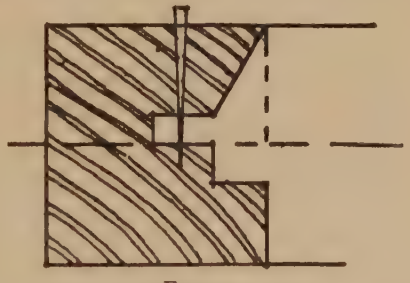


Fig. 19.

Dimensions of the Tusk Tenon.—In determining the proportions and right placing of the various parts of the tusk tenon, it is necessary that the neutral axis or central line of the beam or trimmer be taken as a starting point. The bottom of the mortise should line with this. The result of this precaution is that the tenon will then be in the part of the beam in compression, whereas the tusk, lower down, is in the area subjected to tension. It is, of course, assumed in the above description that the beam and trimming joist are of the same depth, as is shown in Fig. 17. But in such cases as where the common joists are kept up to enable separate ceiling joists to be fixed, the position of the tenon will be higher, and it will be brought thereby some little distance above the neutral axis of the beam. In such circumstances, the determining factor will be a decision as to which of the timbers can best afford any weakening. If the beam has an excess of strength, the tenon will then be kept low, so that undue weakening of the joist may be avoided ; but if the joist has more relative strength to spare than the beam, then the mortise should be cut above the neutral axis of the latter, even though so doing will make the tenon in a high position on the joist. As the beam is the more cut about timber as a rule, it is customary to place the lower edge of the mortise on the neutral axis. The dimensions of the various parts are shown in Fig. 17, above referred to.

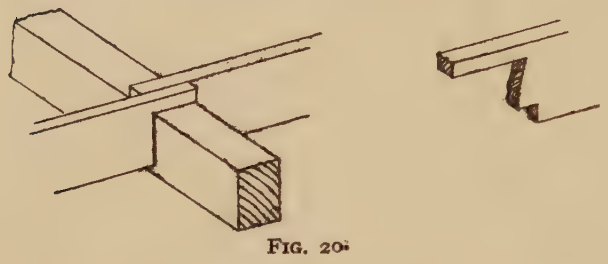


Fig. 20.

Fig. 21.

An alternative form, perhaps scarcely a tusk tenon, but upon the same principles and suitable for use in cases as mentioned above, where it is desired to keep the bottoms of the joists above that of the beam, is shown in Fig. 20. It will be noticed that the beam does not have to be cut through for the tenon, which is run across the top of the beam, and to that extent weakening of the beam is safeguarded against.

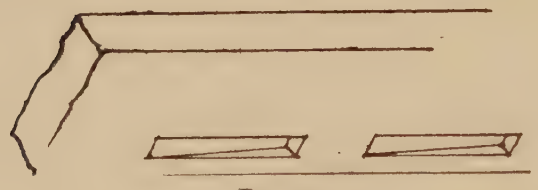


Fig. 22.

In cheaper work and work of a more temporary nature, the beam may be built up of planks, the inner one only being mortised to receive the joists. The inner plank is then spiked to the end of the joists, and other planks spiked to the back of this, until the required breadth is obtained. An alternative form is shown in Fig. 21, but this is one which is not recommended, owing to the tendency of the joist to split.

Joist hangers, as already described (see p. 5), would of course be preferable to the mortise and tenon joint, as all cutting and consequent weakening would be saved. The saving in labour would affect the cost of the hangers, and the use of timbers of slighter dimensions would be possible, as the weakening due to cutting would not have to be accounted for by the extra dimensions of the timbers and consequent extra cost. Though the practice is one which is fairly general in heavier class work, such as factories, it has not been adopted in domestic work, though it is felt that it might well be.

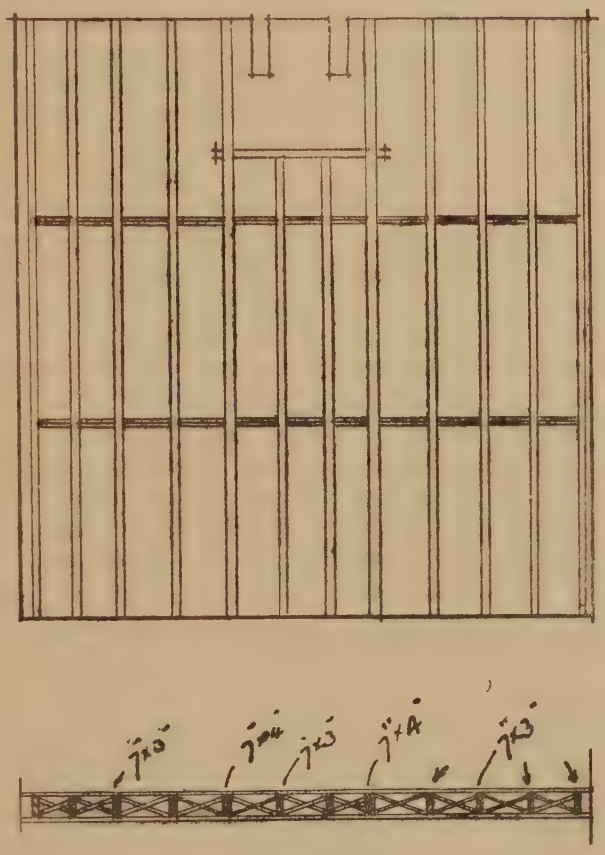


FIG. 23.

THE CHASE MORTISE.—Where it is desired to fix ceiling joists after the beams are fixed, and consequently it is impossible to use the ordinary mortise and tenon, the chase mortise is employed. This consists, as is shown in Fig. 22, of a tenon cut on the ceiling joist, and put into the mortise which is cut out of the fixed beam with a bevelled slide.

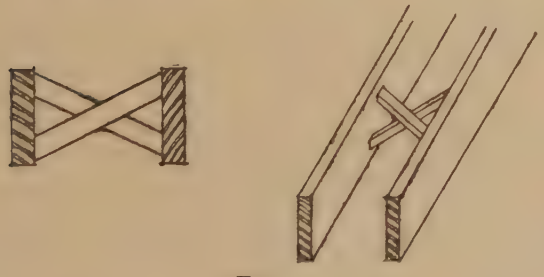


FIG. 24.

HOUSING.—This is the term used to any method of jointing in which the whole end of one timber is let into another timber for a short distance. Ceiling joists are sometimes housed into beams at one end, the other end being treated as described above under "Chase Mortise."

STRUTTING.—Floor joists being so placed that their height is considerably greater than their breadth, have a tendency to twist or to turn sideways on their bases, and to counteract this provision has to be made wherever the span exceeds 8′ 0″. This is effected by means of cross

bracing, known as *strutting*, from one joint to another, at distances from 6′ 0″ to 8′ 0″ apart, in lengths running the whole length of the floor. Beyond providing against the tendency mentioned, this strutting also considerably stiffens the floor, as it communicates stresses from one joist to all the others, and in that sense becomes a tie as well as a shore. It is essential, to obtain the greatest strength, that the strutting should be in continuous lengths from one side of the floor to the other.

Fig. 25.

Herring-bone Strutting.—This method, also termed *cross nogging* and *stemming*, consists of short lengths of battens, 2″ by 1″ or 3″ by 1″ or 3″ by 2″, nailed diagonally between the joist, each batten being cut chamfered and run from the top of one joist to the bottom of the other. It is important that these struts should not be run to the very top and bottom of each joist, but a space of ½″ should be allowed. As nailing in the thin chamfered end is apt to split the wood, in the best workmanship the holes are bored for the nails with an awl. Further, care should be exercised in seeing that each pair of struts bears closely one upon the other at the point of crossing.

Fig. 26.

Herring-bone Strutting in Open Joisted Ceilings.—Where it is desired to show the underside of the floor joists as ceiling joists coming below the ceiling plaster, 2″ by 1″ battens must be nailed along the length of the rafters at from 2″ to 3″ up from the bottom of the joists for the cut laths to be nailed to; and though these form a strengthener to the strutting, the angle formation becomes somewhat flat, and is consequently weakened when the following method may be substituted.

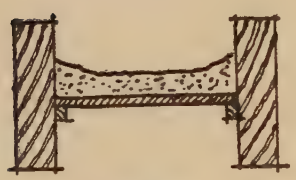


Fig. 27.

Solid Strutting.—This consists of square-cut 1½″ boards fitted in between and at right angles to the joists. The joists may also be bolted from one side of the room to another with a 1″ rod and screw nuts at each end. But this last will be necessary only in the case of floors carrying weights above the normal. Tests prove that it requires three times the load to produce the same deflection in a bridged beam that resulted when the beam was not bridged; from which it will be seen that the strengthening effect of bridging is considerably more than might be expected.

Fig. 28.

Pugging.—This consists of coarse stuff (plaster) mortar and chopped straw, and is intended to deaden sound penetrating from the room above to the room below. To some extent it no doubt does; but where there

is direct communication by means of single joists, it is doubtful if sound penetration can ever be entirely prevented. The mixture is laid on boards themselves laid on $1\frac{3}{4}''$ by $\frac{1}{2}''$ laths, nailed to the sides of the rafters about 3″ from the bottom of the rafter, and about 3″ of sound deadening mixture is used. Pugging may also consist of sawdust or ashes, asbestos or silicate cotton in slabs. Another method is to nail felt from joist to joist, allowing it to sag and filling the bags so formed with any of the deadening mixtures described. This last, though not so frequently met with as the first, is probably a better method, on account of the sound deadening effect of the felt between the floor boards and joist tops.

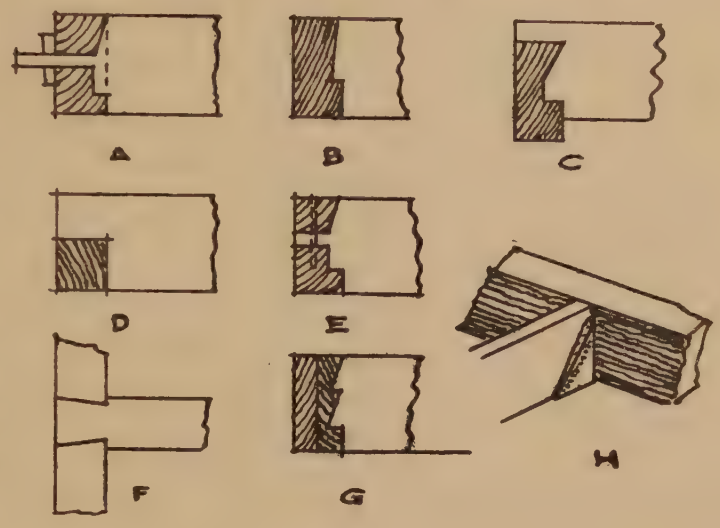


Fig. 29.

Fig. 30.

But in actual experience neither of these methods is satisfactory, as together with the prevention of sound is prevention of a free circulation of air, which is so essential in any enclosed space the structure of which is of wood. A method, possibly more expensive, but preferable in every other way and more effective of the purpose desired —sound deadening—is that shown in Fig. 30. Here, as will be seen, a ceiling beam is inserted between the ordinary floor joists, and this carries the ceiling joists, which are thereby entirely disconnected from the floor boards, with the result that there is no direct communication between floor and ceiling. At the same time, space is left for free circulation of air. And if in conjunction with this air bricks and channels are included in the outer and partition walls, the outer air will be able to penetrate and a continuous movement be kept up in the air within the floor. This will go far to prevent dry-rot.

Fig. 31.

A fourth method, a combination of two of the foregoing, is that shown in Fig. 31, where the ceiling joists run in the same direction as the floor

joists and are separate therefrom, having sound boards and deadening pugging in between them.

Ceiling Joists.—These are separate joists, distinct from floor joists and used, in addition thereto, to carry the lath and plaster of the ceiling. The practice is employed to deaden sound and also to overcome the effect of vibration on the floor above, and so save unsightly cracks appearing in the plaster. There are a variety of ways of fixing ceiling joists. In a single row, they are fixed to the underside of the bearers of the floor and running at right angles to them. And in a double floor they are fixed to the binding joists. As they have the weight of the plaster to carry, they should be fixed at no greater distances apart than 14″ centre to centre of ceiling joist. Whatever depth is decided upon, 2″ width will be found most satisfactory for lathing to and maintaining the key for the plaster, which wider joists would interfere with. They may be fixed by being simply notched and nailed, or mortised as shown in Fig. 10. But as there may be objections against weakening the beam by cutting, a fillet may be nailed thereto and the same purpose served as shown in Fig. 32.

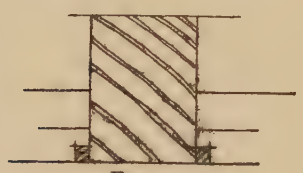


Fig. 32.

As previously mentioned, the *chase mortise* is also employed horizontally for fixing ceiling joists after the beams are in position, as shown in Fig. 10E. Here a binder will be noticed giving support to both floor or bridging joists and ceiling joists ; and the method of attaching this binder to the beam, as shown in Fig. 10F, is preferable to that shown in the following Fig. 10E, on account of the considerable amount of cutting required in the beam. A far preferable method would be the introduction of iron stirrups to carry the ends of the binders, any cutting of the beam being thereby unnecessary.

Types of Floors

Single.—Single floors consist only of floor joists, which are also termed *bridging joists*, spanning the space to be floored and resting on wall plates in the walls. They are unsuitable for spans of over 12′ 0″, as the bridging joists are then liable to sag or bend, resulting in cracked plaster to the ceilings below. Also the full weight of the floor is communicated to the walls through the wall plates, without regard to whether the substructure contains solid work or openings, such as windows and doors. But perhaps the main objection is that they assist in the conduction of sound from the room above. At the same time they are, of course, the cheapest form of floor, and will be the class of floor most frequently employed in small buildings and houses.

Ground Floors of single floor construction have *dwarf* or *sleeper* walls of 4″ thick built under them with wall plates for the joists to rest on at proper intervals. This enables a saving in timber to be effected,

as the floor joists will not need to be of such large dimensions as would otherwise be required.

BRIDGING JOISTS.—These are usually spaced at from 12″ to 14″ centre to centre.

DOUBLE FLOORS.—These are used when the span is too great for a single floor ; in these the bridging joists instead of spanning the whole distance between the walls are supported by intermediate timbers known

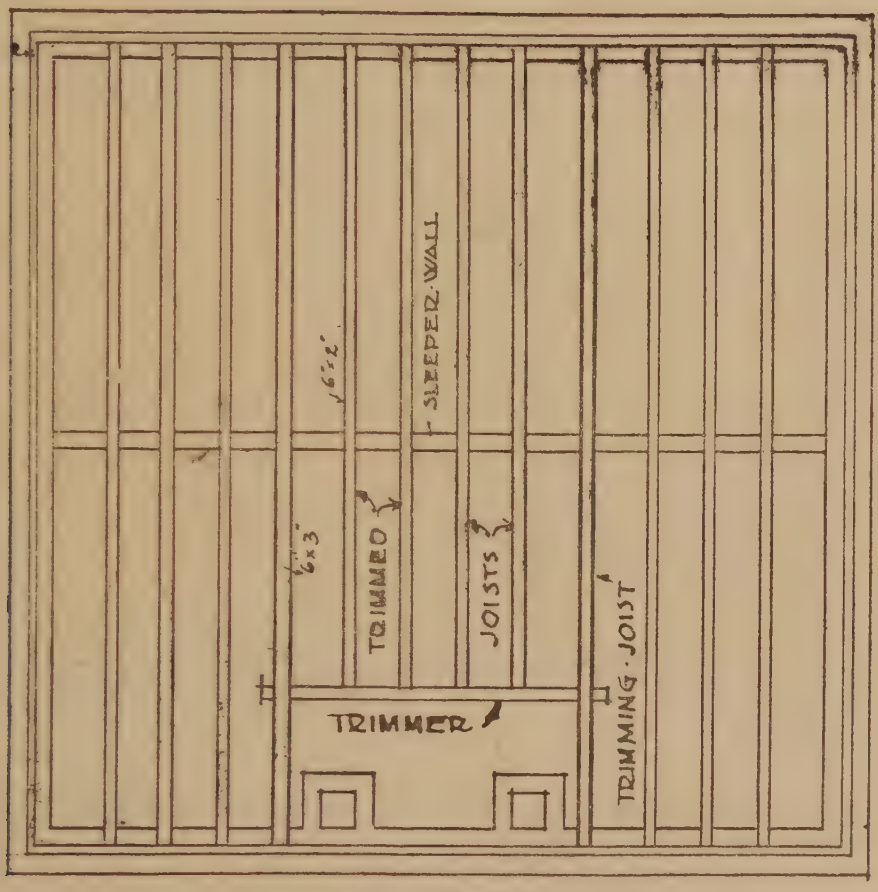


FIG. 33.—SINGLE.

as *binders* or *binding joists*. The actual spans will be anything over 16′ 0″, and the binders will be found to be introduced at intervals of 10′ 0″ in practice, though Tredgold recommends that binders should not be spaced more than 6′ 0″ apart.

With the use of double floors, the objection of sound transmission is removed and the bridging joists are stiffened. The binders also act as ties between wall and wall, but of course they add to the cost of the house, not only in the additional timber and labour their use involves,

but also in raising the structure they add to the amount of external walling necessitated.

As the binders collect the weight of that portion of the floor on either side of them to a distance half-way to the next binder, it will be obvious

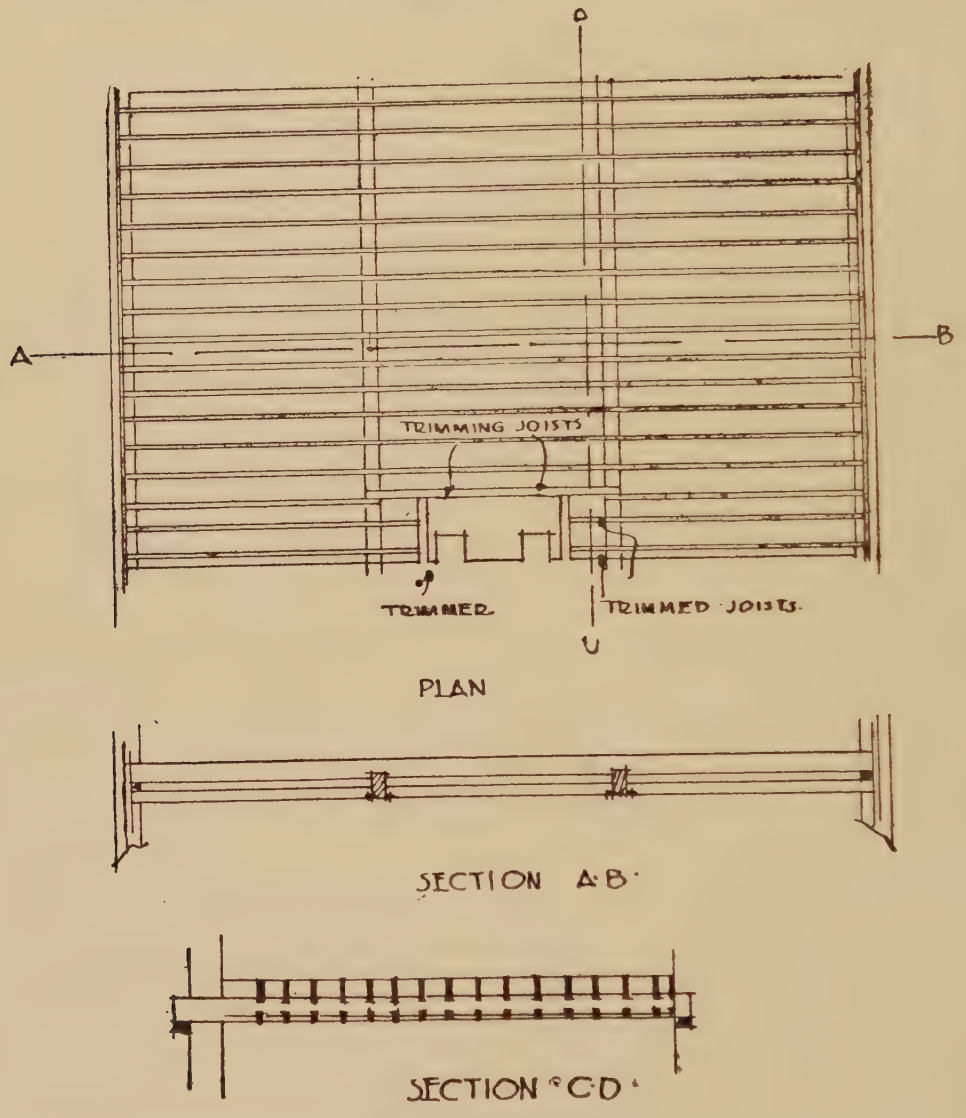


FIG. 34.—DOUBLE.

that they must be so placed as to rest on solid masonry and not above openings.

In Fig. 34 a plan of a double floor is given. The space between the binders and walls is termed a *tail bay*, and that between the two binders a *case bay*.

The binders should rest on stone templates over which a lead pad cut to fit the timber end is placed.

Where flues or other openings and vents occur in walls they should be trimmed in the manner shown in Figs. 33–35.

FRAMED FLOORS are constructed as shown in Fig. 35, and consist of girders placed at from 8′ 10″ apart in addition to the binders. They are used for floors of over 24′ 0″ span, and will be found at the present time in use only in buildings of a cheaper nature, steel and other forms of fireproof construction having taken their place in modern construction.

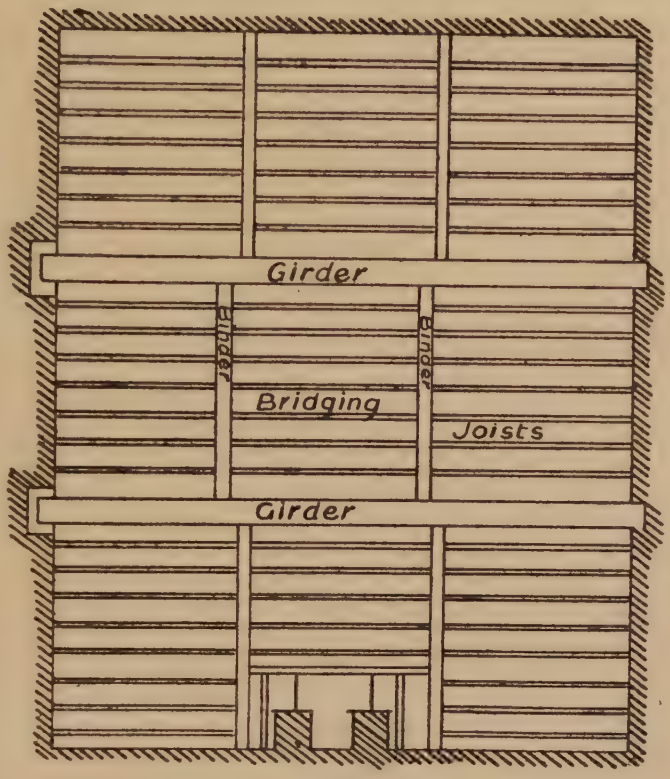


FIG. 35.—FRAMED.

Fig. 37 shows the construction of the joint used in jointing the binder to the beam or girder; from which it will be obvious that the binders must be so placed that they do not come in a continuous line in each bay, as in such circumstances the beam would be so much weakened as to be almost cut in two.

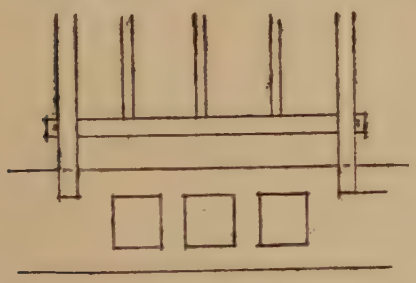


FIG. 36.

An alternative method is shown of jointing the binder to the girder in Fig. 38, from which it will be noticed that in place of cutting an iron stirrup is hung over the girder.

The girders rest on stone templates as in double floors, and the binders are framed into them as above described. Where flues occur in a wall, the floor is supported by a half girder, in order that the joists may not rest upon the wall containing flues.

Combination Floors

Steel and Wood.—Floors with spans over a certain distance would require beams in wood of such large dimensions that they would be too bulky. In such circumstances steel joists, beams and girders are sub-

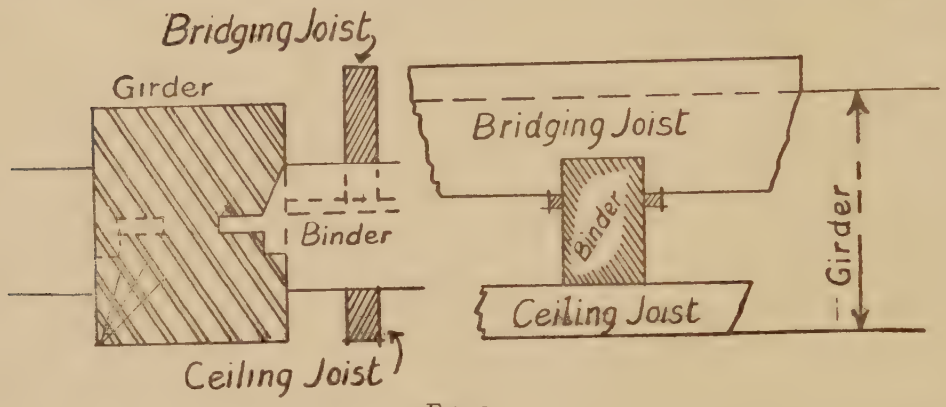


Fig. 37.

stituted for bearers, and the ordinary floor and ceiling joists jointed therewith in the methods described as follows :

Steel Beams.—In Figs. 39–43 are shown the different methods by which wooden beams may be substituted by steel joists and girders. In Fig. 39 a 12″ by 5″ rolled-steel joist is projected below the ceiling, the bridging joists being carried on the top flange thereof and being fixed thereto by $1\frac{1}{4}$″ cradling. In Fig. 40, the same being the case for a still heavier load, the bridging joists are carried by wooden binders, which are bolted to the girder and carried on plates supported by the bottom flange of the girder. In Fig. 41 a rolled joist is substituted for the binder in the thickness of the floor, the bridging joists being supported on plates bolted through the web of the joist and supported by the bottom flange.

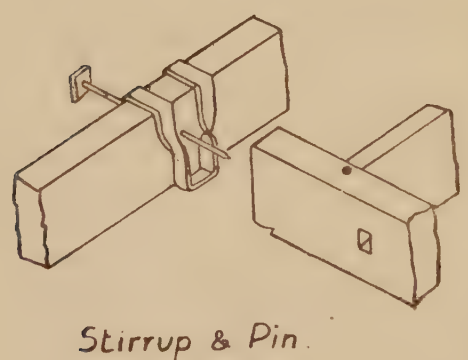


Fig. 38.

Where a compound girder, within the thickness of the floor, is required, the method adopted is that shown in Fig. 42. Here 8″ by 8″ wood binders run at right angles to the boxed girder through the bottom two webs, which are bolted plates on which the binders rest. The ceiling joists and floor joists, running parallel to the girder, are carried on the binders in the manner shown.

Spring Floors

Spring floors for dance halls may depend for their "springiness" upon the lightness of the timber joists, and whilst this elasticity is satisfactory for dancing, the weakness of the construction necessary to give the resilience may be a source of danger when the same floor is subjected to concentrated loads, such as bazaars, theatrical performances or meetings. Morton's Patent Valtor System combines a wooden floor and joists with steel girders in short lengths from 5′ 0″, supported on steel helical springs.

A section through one bay of Valtor floor is shown in Fig. 44, where

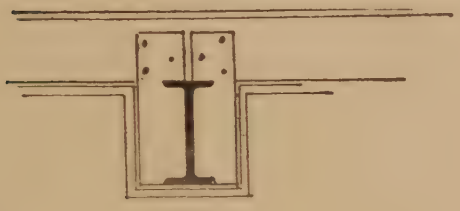


Fig. 39.

Fig. 40.

Fig. 41.

Fig. 42.

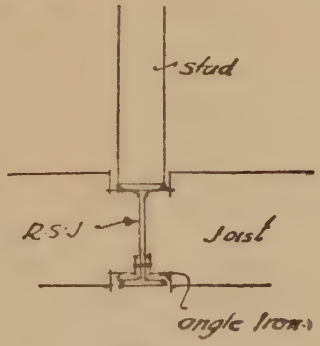


Fig. 43.

the timber floor joists rest upon the top flange of short lengths of steel joist, which are supported at their ends by the steel springs in the manner shown. Upon the wood floor joists are deal battens, about 1″ thick, spaced 14″ apart centre to centre. Upon the battens are laid the floor boards which consist of tongued and grooved boards in narrow widths. Close-grained, well-seasoned oak makes the best floor, but good pitch pine or maple is also used. As will be seen from the section, the end of the floor joist against the walls rests on a timber plate bevelled on its outer top corner to allow for the hinged movement. To assist in this also, it should be noted that the skirting should be raised slightly from the floor boards. In very large ball rooms it is sometimes desired that there should be a fixed border round the room, to allow of seating accommodation. This may be effected by a second solid wood plate at a dis-

tance of 3′ 0″ from the wall ; but it involves no break in the continuity of the flooring, the natural elasticity of the boards bridging the dividing line between the fixed and the resilient portions of the floor.

The cross section is given in Fig. 44, and shows the method by which

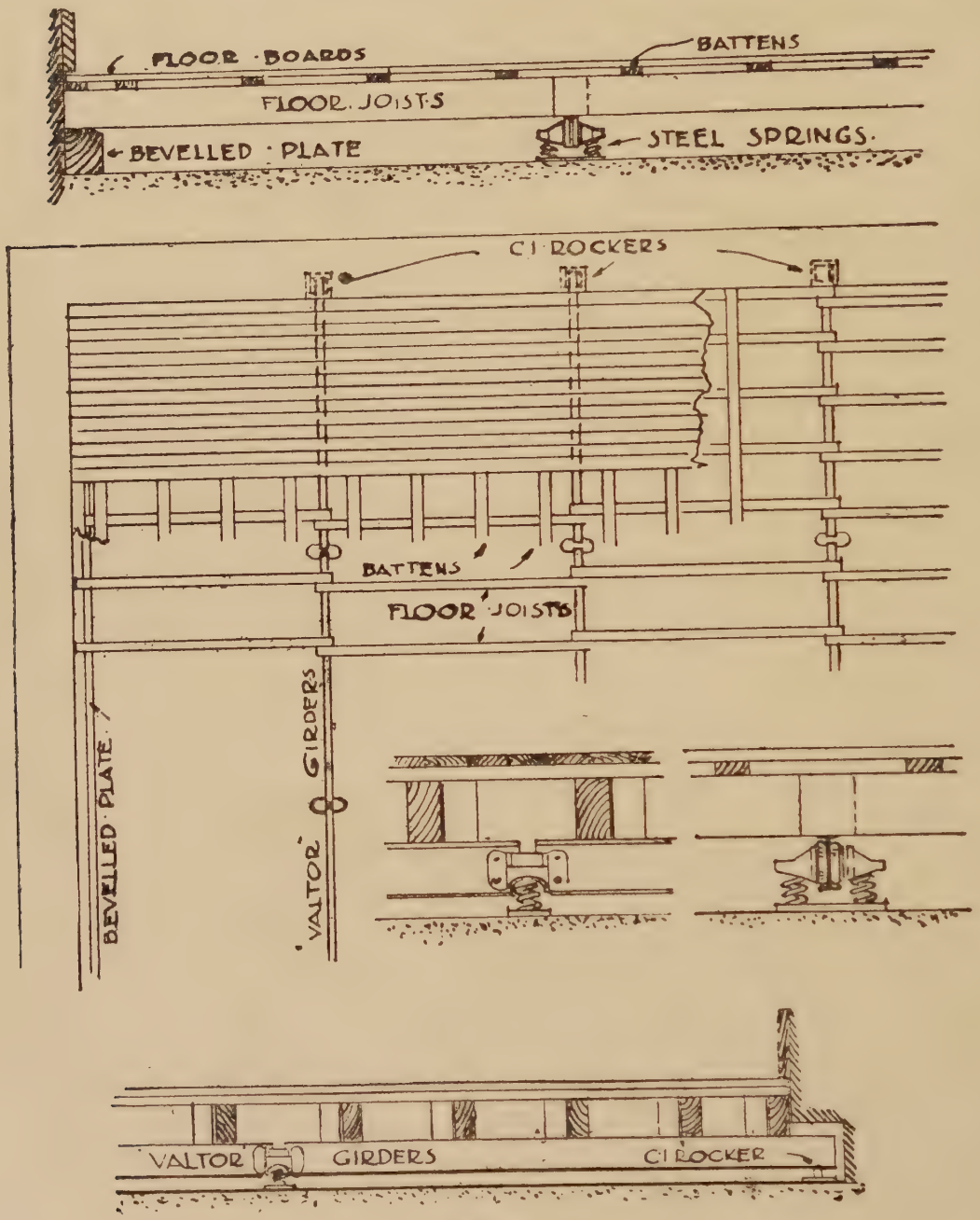


Fig. 44.

the rolled-steel joists are run over a C.I. rocker at their ends against the walls, placed in a chase let into the walls.

FIG. 45.

The Valtor Patent also embraces an automatic locking gear, enabling the floor to be made rigid when desired. But as this necessitates no

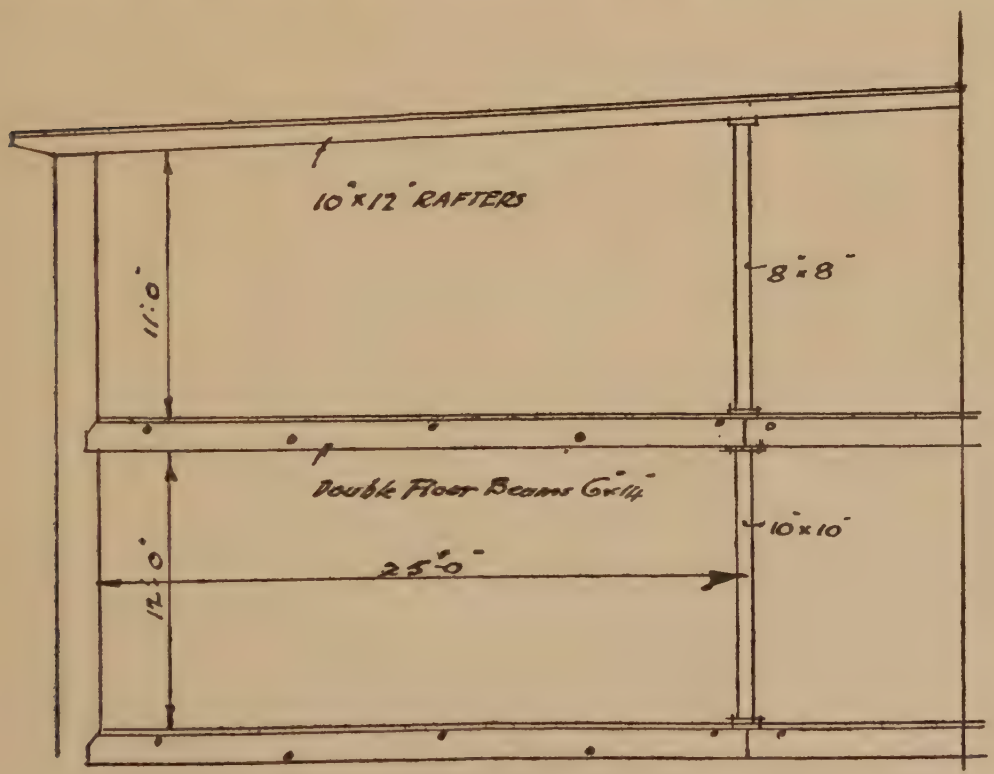


FIG. 46.

alteration in the woodwork save that timber sleepers are here introduced under the springs, no further description is necessitated.

Mill Construction

Mill construction is a form of composite construction used in heavier and cheaper forms of building, into which both wood and steel enter, and is of interest to the carpenter only so far as the woodwork used and the jointing adopted with the steel work are concerned. It is used mostly for buildings of the factory type, and is sometimes termed *slow burning construction*, the motive of the form being to reduce the fire risk to the lowest point possible where wood is used.

To this end the method consists in so disposing the timber in heavy, solid masses as to expose the least number of corners and ignitable projections to fire. Every floor should be separated from every other floor in this type of construction by incombustible stops; and ceilings should be protected with non-combustible sheeting.

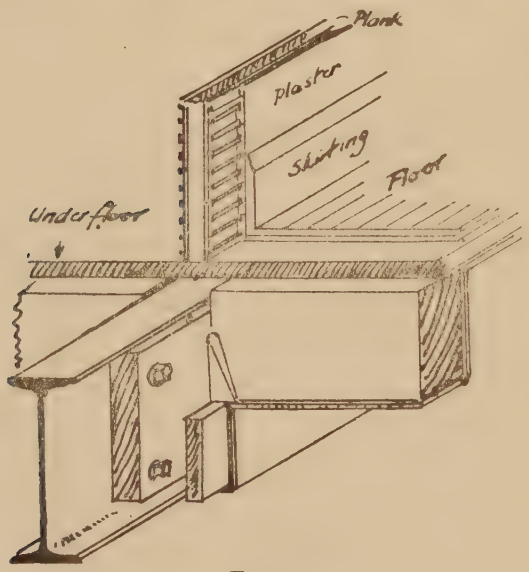


Fig. 47

In Fig. 46 is shown a section through part of a mill built in this method, from which it will be noted that heavy double floor beams are used in conjunction with 10″ by 10″ to 8″ by 8″ posts. These are more generally of cast iron. Fig. 45 shows a one-storey slow-burning machine shop. The method of jointing a steel joist with wooden beams is shown in Fig. 47. In jointing wooden joists to wooden beams hangers of the Van Dorn type are used, as shown in Fig. 38, and Fig. 47 shows a method of building in and anchoring the wooden floor joists. A double floor is also shown in this illustration.

In the last-named method of floor construction, the span of the floors is often so great that timber beams would require to be of such scantlings that they would be altogether too unwieldy. In such circumstances the floors are made up of composite materials, the bridging joists and ceiling joists, as before, in wood and the girders in steel.

Flitched Beams.—Beams may be strengthened without any considerable increase in their bulk by being split in half longitudinally and reversed and bolted together again with a thin wrought-iron plate between them.

Trussed Beams.—A method no longer much in use, owing to the growing substitution of steel girders, is to truss wooden beams by king or queen trusses as is shown in Figs. 48 and 49.

The beam is cut in half and reversed as described above, and a framed truss, consisting of wrought-iron abutments and hardwood struts, is bolted between the two halves.

The two trusses of the types shown in Fig. 49 explain themselves and scarce call for any further comment but that they are now almost obsolete.

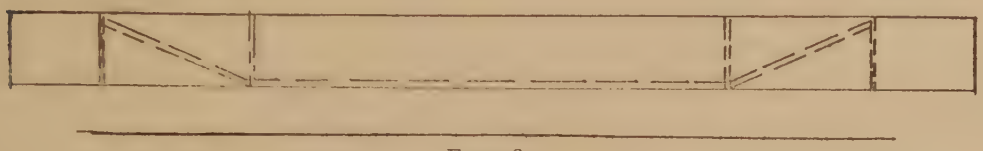


Fig. 48.

Loads on Floors

The following are the approximate loads on floors :

For ordinary dwelling houses	1 cwt. per sq. ft.
,, public halls used for concerts and dancing . .	1½ cwts. per sq. ft.
,, warehouses	2 to 4 cwts. per sq. ft.

In warehouses the heaviest possible load which may be placed upon the floors should be taken into consideration and the floors calculated to

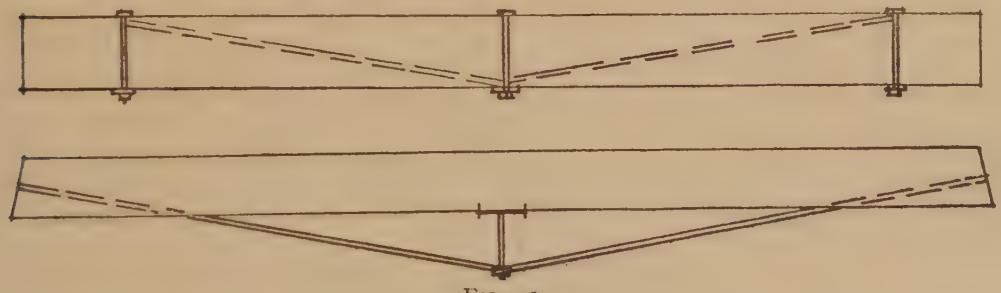
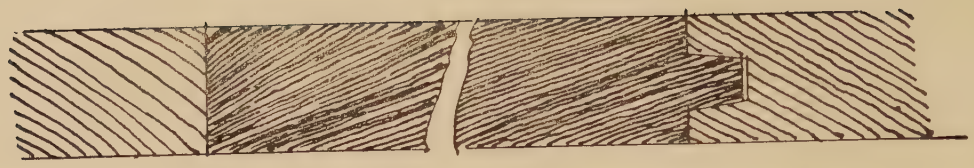


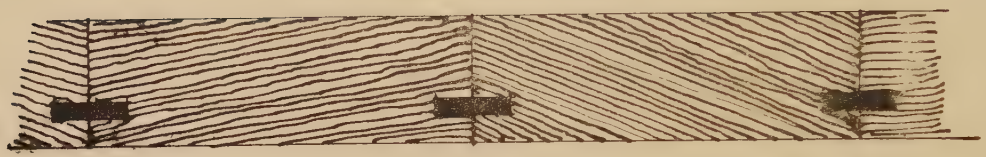
Fig. 49.

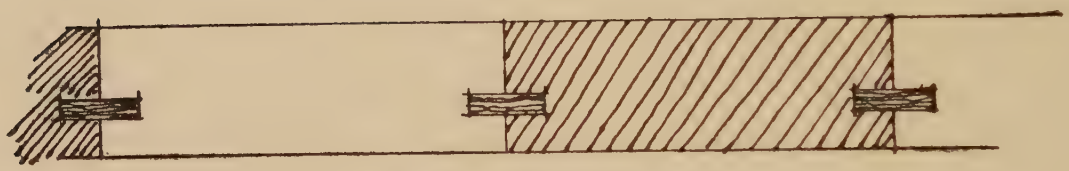
meet this. When timber is laid over several points of support, the strength of the intermediate posts is about twice as much as when cut into short lengths ; hence the advantage of using rafters, bridging joists, purlins, etc., in long lengths.

Floor Boards and Flooring

In England it is customary to lay only one thickness of floor boarding, whilst in American construction, even in the cheapest work, a rough flooring is first laid, often diagonally during the erection of the building, the finish floor covering being laid of narrow boards after the rough construction is finished. The floor covering most commonly used in England consists of boarding 1″ to 1½″ thick and 5″ wide, nailed to the







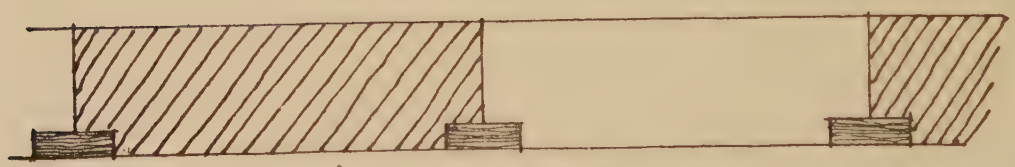


FIG. 50

TYPES OF FLOORING JOINTS.

joists at right angles to their direction. Boards of narrow width open less at the joints and are consequently the best. In old work of the half-timbering days flooring was cut very wide, with the result that it curved and undulated.

Joints

The sides of floor boards are jointed as follows:

Square or Plain Joint.—This is the cheapest method of laying floor boards and consists in simply butting the edges and nailing them to the floor joist with two nails to each joist. The nail heads should be punched below the surface of the floor boards to prevent them from projecting upwards into any floor covering that may be used. In laying, the carpenter will start from one wall, and by means of a cramp, as shown in Fig. 52, applied against every fifth or sixth board, press them tightly together in their lengths. They are then nailed as described. The method known as "laid folding" is a more elementary one, and consists of laying the boards loosely at first. About six boards are laid across

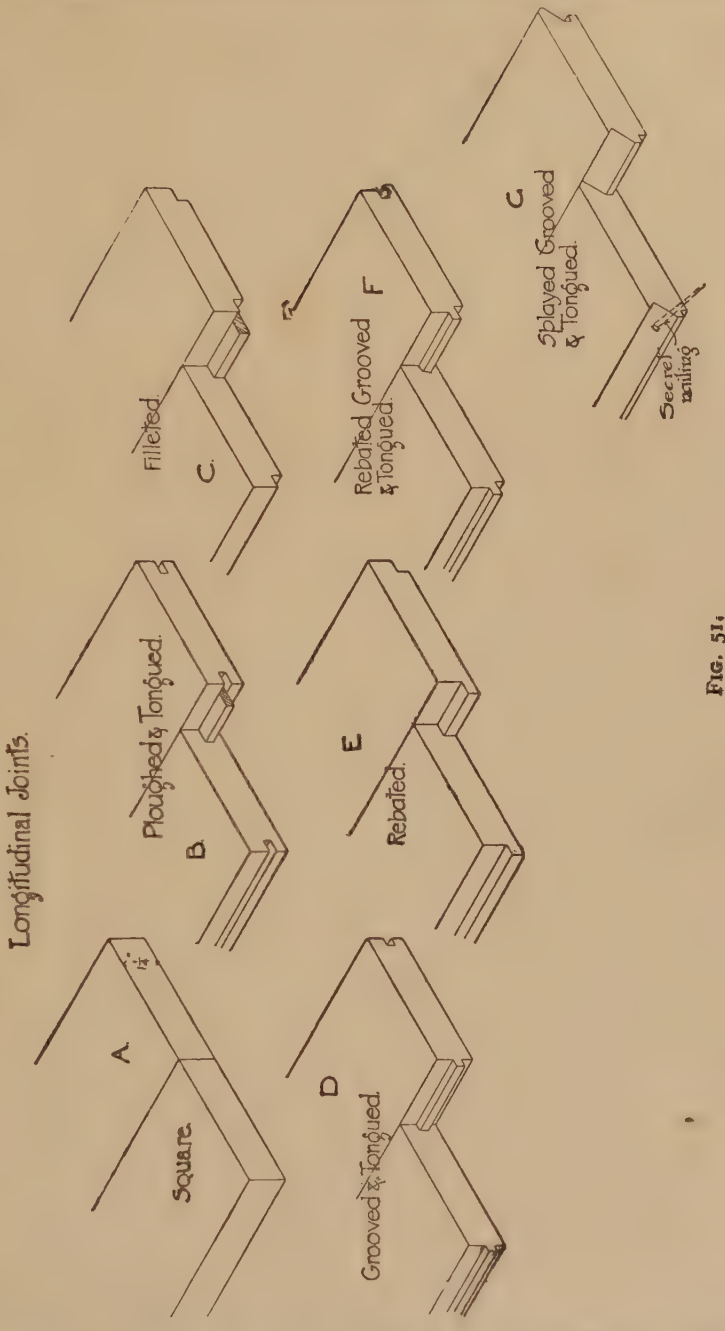


Fig. 51.

the joists without being nailed, loosely touching. One of the outside boards is then nailed, and the position of the other outer board is marked upon the joists, the four intermediate boards are taken up and the outer board nailed a little closer to the nailed one than the position marked. The inner four are then relaid, when it will be found that two of them will not lie flat but bridge upwards. A stout board or a length of floor board is then placed at right angles to these, and one man jumps on the upper end, springing the floor boards into place, whilst another man stands on the lower end. The operation is a cumbersome one and wasteful of labour. And as the alternative is the use of a cramp as already described, which is not expensive and an initial outlay at that, the "laid folding" method does not seem to have much to commend it.

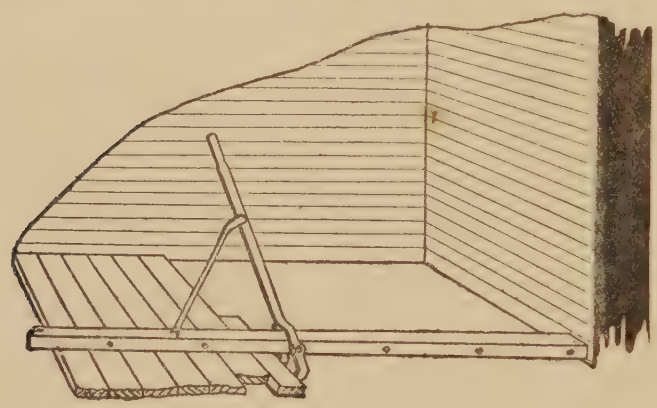


FIG. 52.

REBATED.—Fig. 51, E, shows a rebated joint in which a rectangular section is cut out of the lower edge of one floor board to fit into the upper edge of the next, cut away in a similar manner. This and the following grooved joints are all cut in the shop by machinery, as described in another place. And in rebating, each board comes to the works with a fillet at the top on one side and at the bottom on the other, the operation being performed in the same machine by simply turning over the board after one side has been rebated.

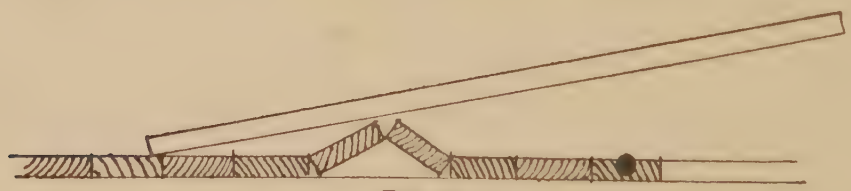


FIG 53.

The advantage of all grooved joints is that they prevent dust and draught from penetrating into and from the space in the thickness of the floor below. At the same time, with the rebated joint, if poorly seasoned wood is used, a considerable shrinkage is likely to occur, widening out the upper joint, and though this does not give access to the space below, it may and does become a receptacle in which dust collects. Another name for this joint, though not one frequently met with, is *fillistered*.

GROOVED AND TONGUED.—This is shown at D, Fig. 51, and is an effective dust-proof joint, but somewhat expensive. As will be seen, a tongue is cut in the middle third of the edge of one board to fit into a similar groove in the other. An objection to this form of joint is that the tongue being thicker consequently a thinner strip is left on the other board above the groove. With much wet from constant floor-washing, this upper strip rots and strips.

REBATED, TONGUED AND GROOVED.—When the tongue of a grooved and tongued joint is not made of sufficient depth, a small amount of shrinkage will cause a gap sufficiently large to permit the dust to be blown through. This is remedied by the method shown at F in Fig. 51, where the lower strip beneath the groove projects farther than the strip above the groove. This joint is also made as shown in Fig. 54, which enables one board to be laid and nailed, and the other board to be slipped in afterwards. The method of nailing is known as *secret* nailing, from the fact that when the floor is laid no nails appear, which is often an advantage.

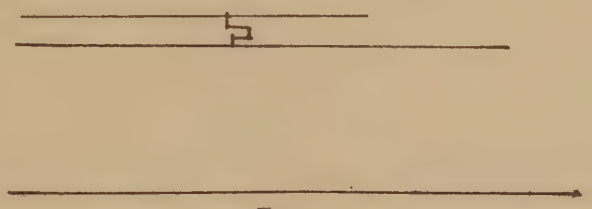


FIG. 54.

FILLETED. — This consists, as shown at C in Fig. 51, of a board rebated on the underside of both edges, the space being filled with a loose fillet inserted at the time of laying. This has the advantage over the ploughed and tongued joint that it is less expensive; but the fillet, being thin, may contract or sag between the floor joists, unless very well-seasoned wood is used. And even then water from washing will affect it deleteriously.

REBATED AND FILLETED.—This, as shown in Fig. 50, is practically the same as that described under "Filleted." In this instance the fillet is made of oak, or sometimes metal, and is only 3/16″ in thickness. It has the advantage that the floor must be worn almost through its entire thickness before the fillet becomes exposed. The fillet being of hardwood is less likely to be affected by water.

PLOUGHED AND TONGUED is that form shown at B in Fig. 51, from which it will be seen that the fillet is here inserted in a narrow groove cut in the centre of the thickness of the floor boards. The tongue or fillet may be of ordinary wood, hardwood or metal, and the reason for its insertion is, of course, the prevention of a through passage for air and dust. Being placed as it is, no sagging, twisting or shrinkage can affect it. This is perhaps one of the most satisfactory of floor joints, and is not an expensive one. It should be noticed that as a safeguard against the tongue being laid bare by wear, it should be placed nearer the underside of the boarding than to the upper surface. Wooden tongues should have a coat of paint before insertion, and iron tongues

should be galvanised to prevent their rusting, swelling and raising the floor boards at their edges and so opening the joints.

SPLAYED, GROOVED AND TONGUED is another name for the joint shown in Fig. 54, under "Rebated, Tongued and Grooved," and also illustrated in Fig. 51 at G.

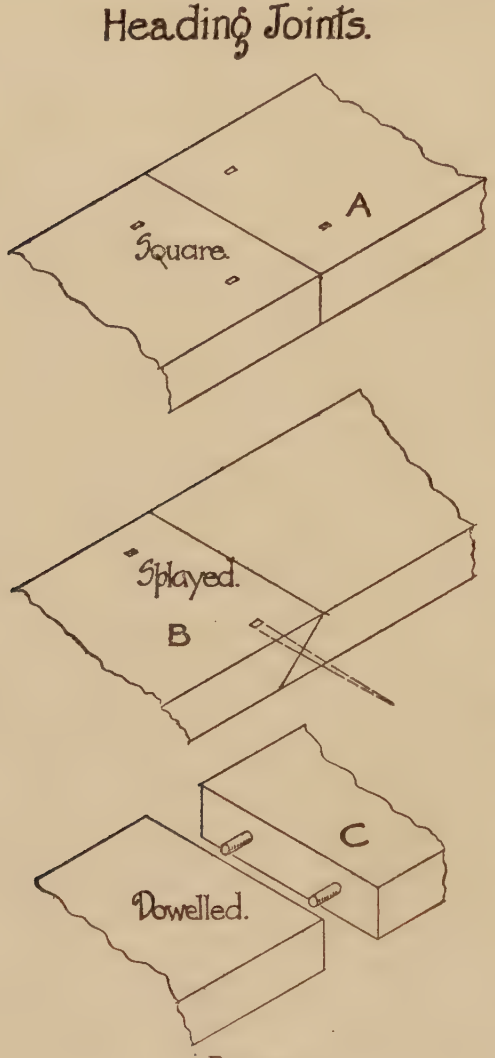


FIG. 55.

DOWELLED JOINTS are a method of pinning the floor boards together with small oak pins let into holes on the edges of the boards. These should be so placed as to come over the spaces between the floor joists, as over the joists they are unnecessary, the boards being held down at those points by the nails. The nails may be driven obliquely into one edge of the floor board, nails and labour being saved by this and *secret nailing* resulting.

Plain jointed and rebated flooring is used in the cheaper classes of work, and rebated and filleted and ploughed and tongued are used for heavier work, such as warehouses, factories and barracks; whilst grooved and tongued, and dowelled flooring are used in high-class floors, such as good houses and office buildings, banks, etc. Rebated, grooved and tongued flooring is only used where very superior workmanship is desired.

Rebated ; rebated, grooved and tongued ; and grooved and tongued, require a larger quantity of boarding to cover a given area than is the case with the other types mentioned.

POINTS IN CONSTRUCTION

All classes of wood floors above described when laid should be covered with sawdust to prevent dirt and plaster and paint from soiling their surfaces. As has been said, floor boards will be prepared in the shops, but they should be brought on to the site as soon as possible after the contract is signed and stacked in such a manner under a rough covering, having roof but no sides, in order that the air may pass through the stack

and complete the seasoning, which may have been kiln-dried, with the result that the timber still retains a certain amount of "greenness."

Floor boards should be *rift*—that is, sawn at right angles across the annularrings—thus saving shrinkage.

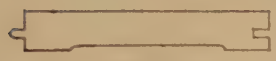


Fig. 56.

HEADING JOINTS.—The ends of floor boards, when not of sufficient length to extend across the whole width of the room, are jointed as follows and as shown in Fig. 55.

SQUARE.—This is most commonly met with, and consists of a plain square ended butt joint.

SPLAYED.—However, where it is desired to make a joint less liable to open, the ends are cut on the splay, as shown at B. This method also has the advantage of saving nailing.

DOWELLING.—Similar to that used in side jointing, as already described, consists of two oak pins or metal dowels as shown at C.

BREAK JOINTS.—Heading joints should never come in line on two adjacent floor boards, and the joint should come over a joist.

SCREW DOWN.—All boards over pipes, joints and bell wires should be square jointed and screwed down with brass cups and screws.

LOOSE RUNS IN ROOFS.—Loose floor board runs should be laid in roofs, giving access to cisterns, wiring and pipes.

DOUBLE FLOORING.—As has already been stated, in America it is customary to lay floors of two thicknesses of floor boards, and the practice might very beneficially be more generally adopted by ourselves. So far, it is only met with where very superior finish is desired. The

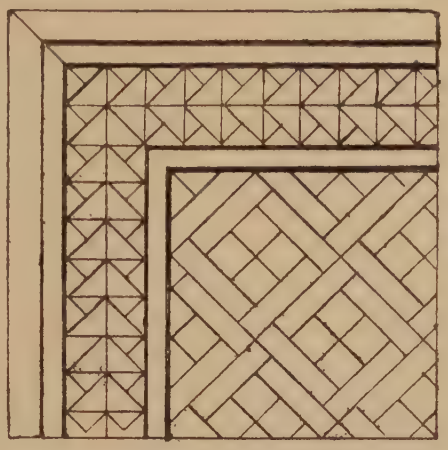


Fig. 59.

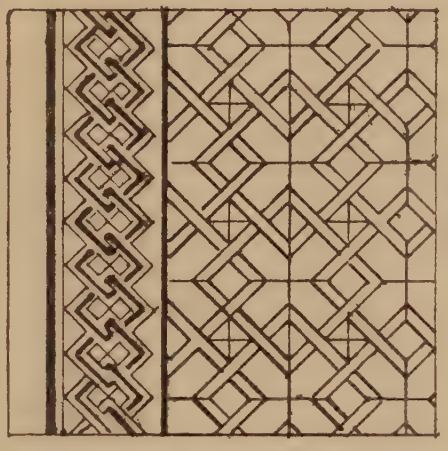


Fig. 58.

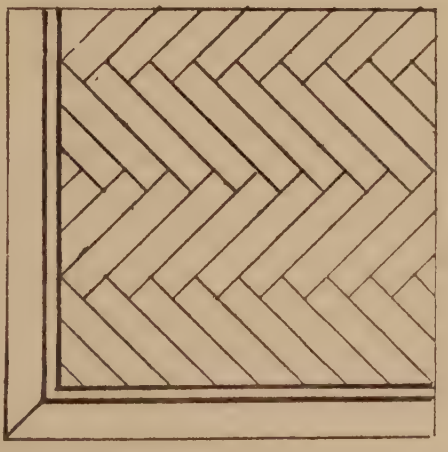


Fig. 57

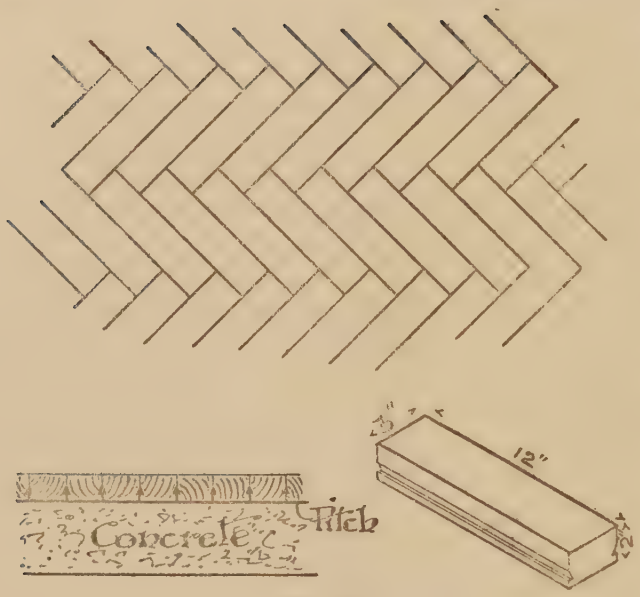


Fig. 60.

lower layer consists of $\frac{3}{4}$" deal laid on the joist in the usual manner. The grounds, joinery, skirtings are then fixed and the plastering is completed. The upper floor is laid at the completion of the works, consisting of narrow 2" to 3" hardwood battens nailed across the under flooring and fixed with dowelled or other secret nailed joints. Where a valuable wood is used and a polished finish is desired, the boards should be glued.

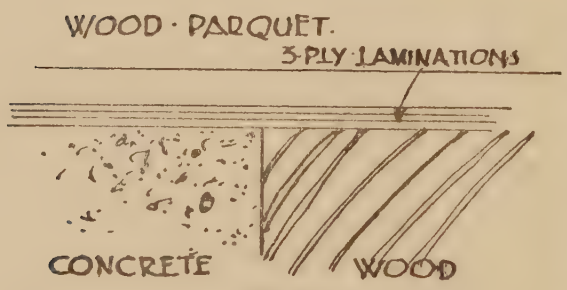


Fig. 61.

In America for floors that are to be carpeted, spruce and pine are used, and where wear is to be expected, as in kitchens, Southern Yellow or Georgia pine may be used. Ordinary flooring is $\frac{7}{8}$" thick with the bottom side left rough, but for shops, public corridors and similar places $1\frac{1}{8}$" flooring is used, both for stiffness and durability. The better qualities of matched flooring are of the sections shown in Fig. 56. This method is adopted to make the upper floor bind with the lower and as a prevention against warping.

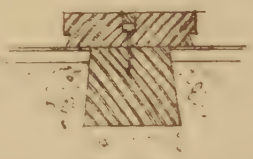


Fig. 62.

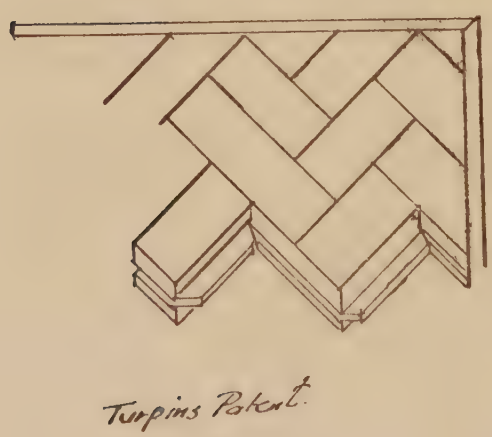


Fig. 63.

Paper under Upper Floor.—For the prevention of sound penetration and for warmth, a building paper or felt may be placed between the two floorings.

Wood Block Floors.—Wood

blocks are generally laid by specialists providing them. They may be laid diagonally in a herring-bone pattern, as shown in Fig. 57, or they may be laid in parallel rows, or alternatively, as shown in Figs. 58 and 59.

Fig. 64.

They may be laid on under floors as last described, but used on the ground floor, a bed of concrete would be preferable. The blocks are laid in mastic or pitch, and measure 9″ by 3″ by 1½″ deep. They may be tongued and grooved, or dowelled with hardwood pins.

Fig. 65.

Fixing Blocks, as shown in Fig. 62, are creosoted and bedded in concrete at 3′ centres, and the floor blocks covering immediately over them are screwed down, the screw holes being *pelleted*, as shown in Fig. 62. Also for the purpose of fixing hardwood floors of oak boarding, as is

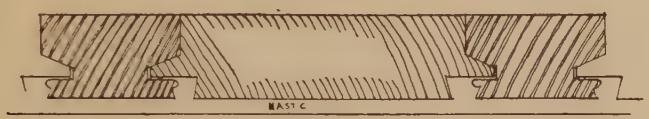


Fig. 66.

sometimes done direct on to concrete, dovetailed fillets, as shown in Fig. 64, are embedded in the concrete, and the boards either nailed or screwed thereto.

Sizes of Floor Timbers

TABLE OF SCANTLINGS

Recommended by Tredgold for *Single* or *Bridging Joists* of Baltic pine for different spans from 5′ 0″ to 25′ 0″, the distance from centre to centre of the joists being 12″.

Length of span in feet.	Breadth 1¼″.	Breadth 2″.	Breadth 2½″.	Breadth 3″.	Breadth 4″.
	Depth in inches.	Depth in inches.	Depth in inches.	Depth in inches.	Depth in inches.
5	5¾	5¼	4¾	4⅜	4
6	6¼	5¾	5⅜	5	4½
8	7¾	7	6½	6¼	5¾
10	9	8	7½	7	6½
12	10	9¼	8½	8	7¼
14	11	10	9½	9	8
16	12¼	11	10½	9¾	8⅞
18	13¼	12	11¼	10½	9½
20	14¼	13	12	11¼	10¼
22	15	13¾	12¾	12	11
24	16	14¾	13¾	12¾	11¾
25	16½	15	14	13	12

TABLE OF SCANTLINGS

Recommended by Tredgold for *Binding Joists* of Baltic pine for different spans from 5′ 0″ to 20′ 0″, when the distance from centre to centre is 6′ 0″.

Length of span in feet.	Depth 6″.	Depth 7″.	Depth 8″.	Depth 9″.	Depth 10″.	Depth 11″.	Depth 12″.
	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.
5	4¾	3	2	—	—	—	—
6	6¾	4	3	2	—	—	—
7	—	5½	4	2¾	2	—	—
8	—	7	5	3¾	2¾	2	—
10	—	—	8	5½	4	3	2½
12	—	—	—	8	6	4½	3½
	Depth 13″.	Depth 14″.	Depth 15″.				
	Breadth in inches.	Breadth in inches.	Breadth in inches.				
14	—	—	—	—	8	5¾	4½
16	4½	3¾	3¼	—	10½	7¾	6
18	5¾	4¾	4	—	—	10	7½
20	7¼	6	4¾	—	—	—	9½

TABLE OF SCANTLINGS FOR GIRDERS OF BALTIC PINE

Recommended by Tredgold for different spans from 10′ 0″ to 36′ 0″ girders, 10′ 0″ apart from centre to centre.

Length of span in feet.	Depth 10″.	Depth 11″.	Depth 12″.	Depth 13″.	Depth 14″.	Depth 15″.	Depth 16″.	Depth 17″.	Depth 18″.
	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.	Breadth in inches.
10	7½	5½	4½	3½	2¾	—	—	—	—
12	10½	8	6	5	3¾	3¼	—	—	—
14	14½	10¾	8½	6¾	5¼	4½	3½	—	—
16	18¾	14	11	8¾	7	5¾	4¾	4	—
18	—	17¾	14	11	8¾	7¼	6	5	4
20	—	—	17	13½	10¾	9	7¼	6	5¼
22	—	—	—	16½	13	10¾	8¾	7½	6¼
24	—	—	—	19½	15½	12¾	10½	8¾	7½
26	—	—	—	—	18¼	15	12¼	10½	8½
28	—	—	—	—	—	17¼	14¼	11¾	10
	Depth 19″.	Depth 20″.	Depth 21″.						
	Breadth in inches.	Breadth in inches.	Breadth in inches.						
30	9¾	8½	7¼	—	—	19¾	16¼	13⅝	11½
32	11	9½	8¼	—	—	—	18½	15½	13
34	12½	10¾	9½	—	—	—	—	17⅝	14¾
36	14	12	10½	—	—	—	—	19½	16½

CHAPTER II

ROOFS

Timber Framing—Wind and Snow Pressure—Variations—Dead Loads—Methods of Computation—Types of Roofs (Flat, Single Span, Double Span)—Rules for Computing Sizes of Timbers—Table of Scantlings—Scantlings for Purlins—Scantlings for Rafters—Construction and Joints—Fishing—Lengthening Wall Plates and Ridge Boards—Wall Plate Angles and Transverse Joints—Bevelled Halving—Dovetailing and Notching—Beams and Plates—Ceiling Beams and Joists—Chase Mortice—Rafters, Plates and Ties—Parts and Types—Prevention of Shearing in Abutments—Tensile Compression and Shearing Strength—Church Spires—Angles and Weights of Roof Coverings—Economical Roofs.

Timber Framing to Roofs

Much has been written of the expensive nature of the steep pitched roof as built in England, and various suggestions for alternative designs of a cheaper kind have been made. But the deciding factor of pitch to roofs is not merely one of personal taste ; it is climatic. Though even if it were, how there could be found anyone to prefer a flat roof to a steep pitched, well-overhung roof is difficult to understand.

The pitch of roofs in the various countries of the world has been determined by experience of what form of roof has been found most effective in protection against the prevalent climatic condition. In countries where there is much snow, for instance, as in Switzerland, whilst the pitch must not be too steep, or the snow would slide and fall in mass, yet the essential necessity is a wide overhang to the eaves and verges to carry the snow and water, when the snow melts, well away from the walls and foundations. In countries where the sun is strong and shines on most days, a wide overhang is desirable for the purpose of shade, and there the flat roof, where little rain falls, is a reasonable form. But in countries like ours, where there is something of every form of weather conditions known in all climates, the construction of the roof is a matter of very considerable importance. And this is just the reason why, so much attention having been given to the subject, the roof is such a feature, giving so decided a character to the English house. Here the sun is at no time overpowering for long, though at midsummer a certain amount of shade is acceptable, and consequently the wider the overhang possible, having regard to good construction and proportion, the more useful will the roof be found from that point of view. That snow does fall here and lie long enough to collect, necessitates a pitch not too steep. Yet in a country where so great a quantity of rain falls as in England, the steeper the pitch the more serviceable the roof on the majority of days throughout the year. Consequently, in summing up we find ourselves

confronted with conditions which render necessary a roof of a pitch as steep as may be to cast off rain, yet not too steep to allow the snow to lie and to disappear naturally by melting and not sliding. Perhaps the most suitable pitch for practical purposes in England is one of 45°. But, for some optical reason, this angle never looks right. If a degree or two more cannot be afforded, and of course the higher the roof the more timber and other materials required in its construction, then a degree or two less will be found to have a better appearance than an exact 45°.

The subject is also affected by the nature of the roof covering that it is decided to adopt; the lighter the material the steeper should be the pitch to prevent the wind from getting underneath and raising up the covering. The following are the most customary pitches for the usual roofing materials:

Tiles, 45°.
Slates, 30°.
Sheeting, under 30°.

The weight of snow on roofs of various pitches is given in the following table, taking for a basis a $\frac{1}{2}$ pitch Southern Counties as 0 lb. per square foot to extreme Northern Counties with a pitch of $\frac{1}{6}$ as 45 lbs. per square foot.

	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$
Southern Counties . . .	0–0	0–3	0–5	5	5
Central Counties . . .	0–5	7–10	15–20	22	30
Northern Counties . . .	0–12	12–18	25–30	37	45

Wind and Snow Pressure

It is advisable in our climate, in reckoning the requisite strength of roof timbers, to allow for both wind and snow pressure together, and the following table gives the weight in pounds per square foot of roof surface on the various pitches.

PITCH

60°	45°	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$
30	30	25	25	35 to 22	40 to 20

Variations

The following variations will be borne in mind in determining the maximum stresses:

1. Stresses due to permanent loads.
2. Snow covering one side of roof.

FIG. 67.—ONE OF THE BAYS OF WESTMINSTER HALL ROOF, WITH TREFOIL CARVED SPANDRELS.

3. Snow covering entire roof.
4. Wind on side of truss near the expansion end.
5. Wind on side near the fixed end.

It is generally assumed that the maximum wind pressure and the snow load cannot act on the same half of the truss at the same time, hence the combinations for maximum stress will be either case 1 and 3 or cases 1, 2 and 4 or 5.

Dead Loads.—The dead load of roof and truss per square foot of roof surface is made up as follows :

	lbs.
Slate	7¼
Sheeting	3
Rafters	3
Purlins	2
Truss	3
	18¼

Method of Computation

For a pitch of 40° the combined wind and snow load would be about 28 lbs., which makes the total roof load 46¼ lbs., say 48 lbs. Where the

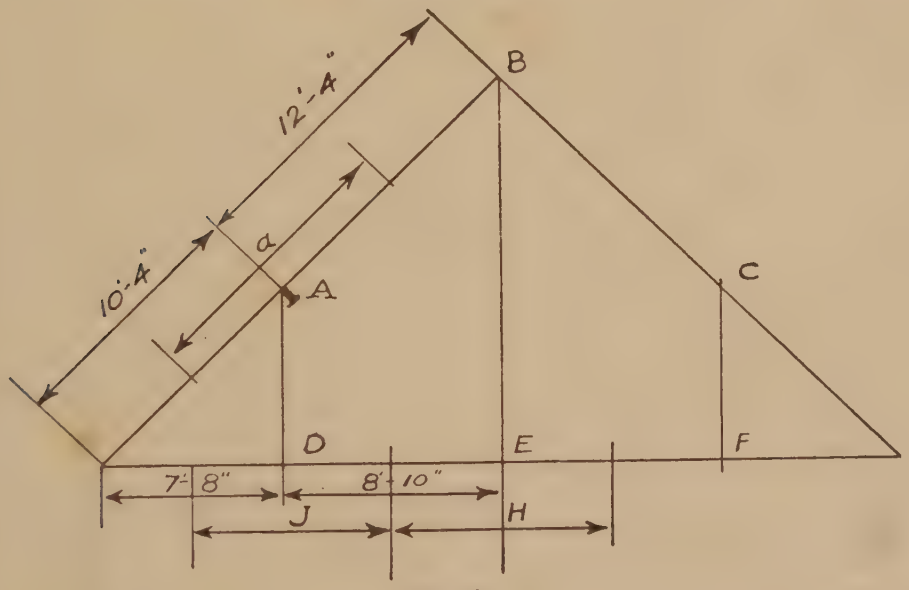


Fig. 68.

distance of the length of roof supported by the truss is 13′ 0″, the root area supported by the purlin A will be equal to the distance *a* multiplied by 13′, *a* equals half distance from wall plate to next purlin or $\frac{22' 8''}{2} = 11' 4''$.

So that roof area supported at joint A = 11′ 4″ × 13 = 147⅓ sq. ft.

In the same way the roof area supported by the purlin at B will be found to equal $160\frac{1}{3}$ sq. ft. Roof area × load per sq. ft. (48)

= for A = $147\frac{1}{3}$ × 48 = 7,072 lbs.
= ,, B = $160\frac{1}{3}$ × 48 = 7,696 lbs.
= ,, C = A = 7,072 lbs.

Add ceiling area at $d = g$ × 13′ 0″ = $8\frac{1}{4}$ × 13 = $107\frac{1}{4}$ sq. ft.
,, ,, ,, ,, $e = h$ × 13′ 0″ = $8\frac{5}{6}$ × 13 = $114\frac{5}{6}$ sq. ft.

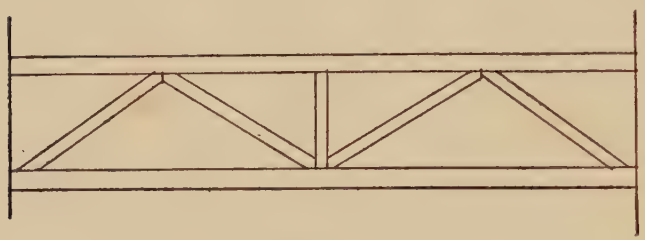


Fig. 69.

Rafters and ceiling joists being 2″ by 8″ and the joists at 16″ centres, the weight of the ceiling may be taken as 3 lbs. per sq. ft. and 10 lbs. for lath and plaster. Allowing for any superimposed load on ceiling joist, say 16 lbs., making weight at $d + f$, $107\frac{1}{4}$ × 18 = 1,930 lbs., and weight at c, $114\frac{5}{6}$ × 18 = 2,067 lbs.

Types of Roof

Flat Roof.—As has been said, the flat roof is not suitable for use in ordinary houses in this country. But in certain positions, such as interior flats, though these should be resorted to only where no other form is possible, and for factory, office, and other buildings of a larger nature, a flat roof is rendered a necessity by the width of span. The type made use of in such buildings is that known as mill construction in America. The term flat is, of course, a misnomer, a certain amount of pitch being necessary for drainage, for which $\frac{1}{2}$″ to the foot will be found to give all that is requisite.

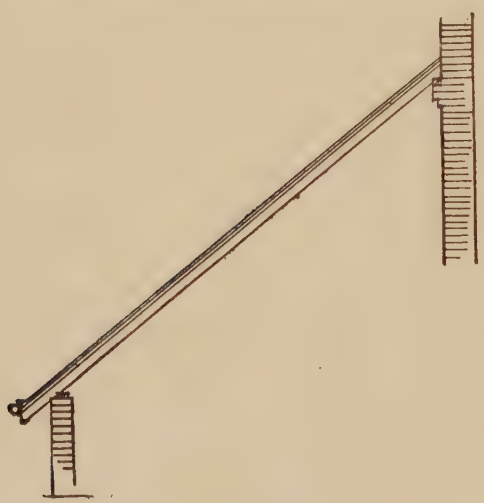


Fig. 70

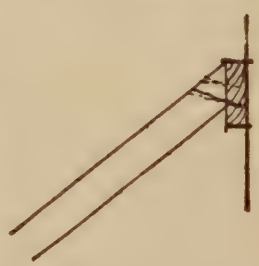


Fig. 71.

The construction is the same as that described for floors to underside of the roof forming the ceiling for the upper storey. But where the span is too great to allow of a single joist, trussed girders will be required as purlins, the joists being then run from girder to girder and at right angles to the span. And for protection against

heat it will be found advisable to suspend the ceiling from the roof rafters.

The means of suspension may be formed as a truss, and the two pur-

Fig. 72.

Fig. 73.

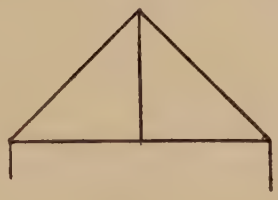


Fig. 74.

poses served at once in the manner indicated in the accompanying diagram.

Single Span.—The component parts of the simplest type of single-span roof merely consist in rafters running from one wall at a high level to another at a low. These require plates for fixing their end on either wall, and to enable the rafters to form ties to the walls as well as supports to the roof covering.

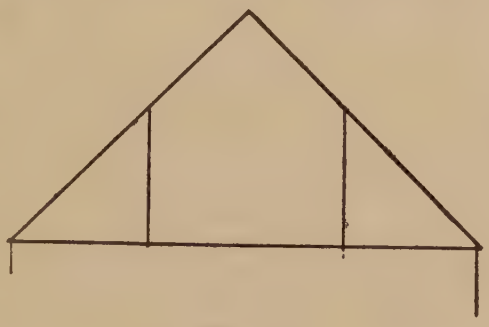


Fig. 75.

In the diagram the rafters are shown spanning from one wall to another at different heights as mentioned, and the wall plates fixed on either wall. Over these the rafters may be simply laid and spiked, but more usually they are notched with a triangular cut to fit. The

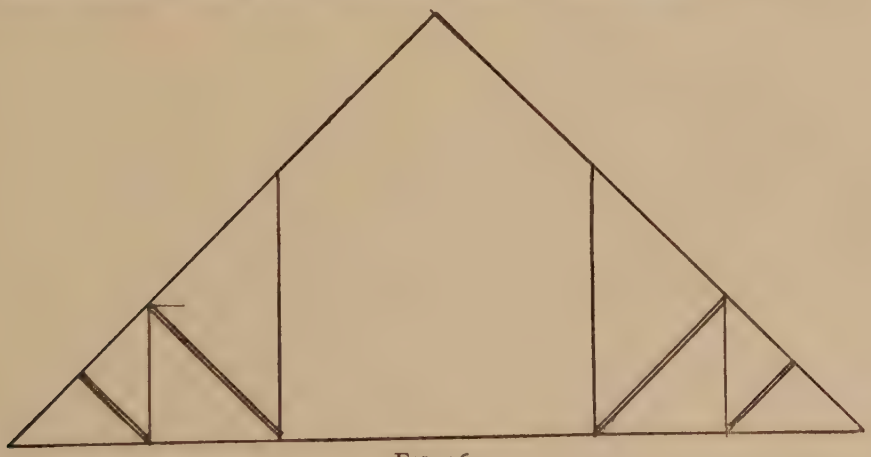


Fig. 76.

rafters are then nailed to the wall plates. As an alternative method, the upper wall plate is sometimes merely a board 2″ by 6″ or 1″ by 6″ plugged

and nailed to the upper wall, and the top ends of the rafters are cut with splay ends to fit against the wall plate and nailed. But the method is not recommended, owing to the fact that any settlement of the lower wall puts too great a strain on the nails.

Double Span.—As the name suggests, or as sometimes called, couple-roofs consists of two rafters coming together at a point known as the ridge or apex. For small spans up to 8′ 0″ to 10′ 0″, this is all that is required, but above that distance certain strains are set up which call for additional timbers. Such a form naturally tends to spread at the feet and to push out the walls, thus calling for a tie running between the rafter feet. Beyond a certain length this tie itself tends to sag under its own weight, and to counteract this a vertical tie or ties must be introduced. Up to span of a certain distance as given below, a single tie suffices, and over that distance two ties are required. The single tie is known as a *king post truss*, and the double as a *queen post truss*. King post trusses are used in spans from 20′ 0″ to 30′ 0″, and queen post trusses from 30′ 0″ to 45′ 0″. Over 45′ 0″ span up to 60′ 0″, double queen post trusses are required as shown.

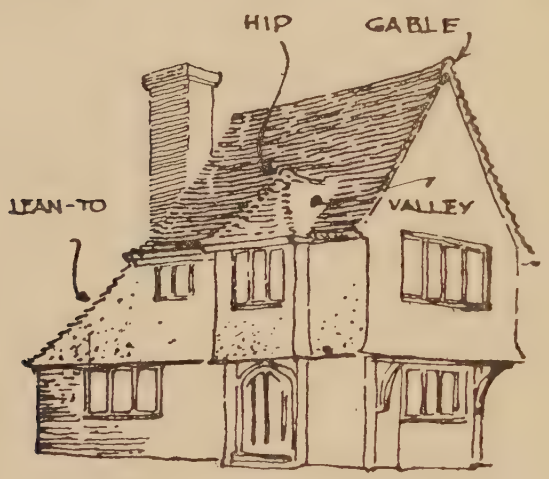


Fig. 77.

Roofs

General Definition.—The roof is that portion of a building which spans the walls at its topmost part. It serves the double purpose of a tie to the walls and a protection against the weather, and may be broadly divided into two parts—a covering and the framework structure necessary to carry that covering. It is in the construction of this framework that the work of the carpenter enters as for the majority of buildings; though portions may be of metal, the main members are built of wood.

Definitions of Parts Used and Types of Roofs

The following are the simple terms given to the various shapes and parts of roofs:

A Lean-to Roof consists of a single slope from a higher to a lower wall, as is often seen in sculleries to suburban houses and outbuildings.

A "V" Roof.—Two lean-to roofs inclined downwards towards a central gutter is termed a "V" roof.

An "M" Roof, or double gabled, consists of two ridged roofs running parallel with a central gutter.

A Gabled Roof is the term applied to a roof consisting of two runs of rafters springing from the side walls of the building and meeting at an apex or ridge, the end walls being formed into a triangle at the top to fill the span so formed.

Fig. 78.

A Hipped Roof is similar to a gable, in so far as its central portion is concerned, but the front and rear walls, instead of being carried up, terminate at the eaves, from where rafters spring in a similar manner to those from the side walls. The effect given is that the corners of the gable roof

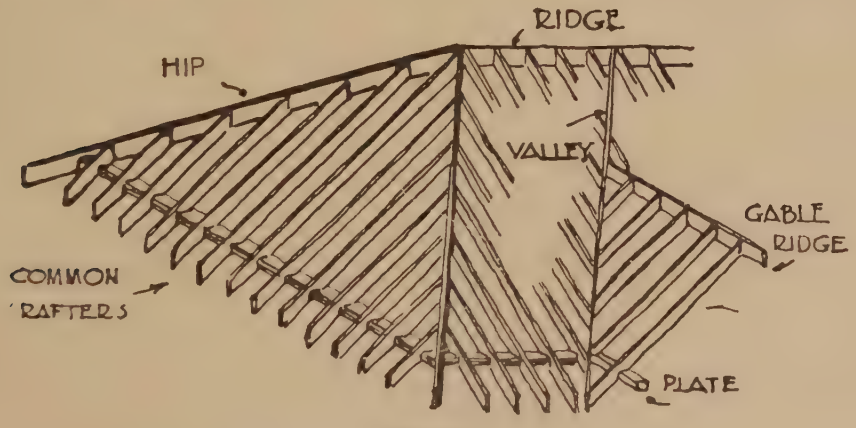


Fig. 79.

are cut off, as shown in Fig. 77. The gutter is continued all round the hipped roof.

RAFTERS.—The timbers running from one point of support to another in a roof are termed rafters.

RIDGE.—At the point of meeting of rafters—that is, at the top or apex—a board is run parallel to the walls from which the rafters spring, and on to the vertical sides of this board the rafters rest, being fixed thereto. This is termed the ridge.

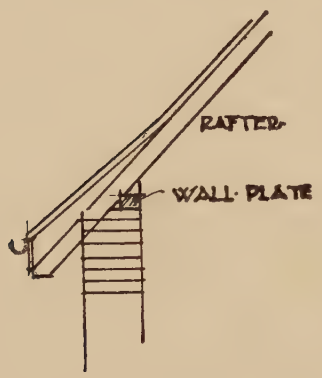


FIG. 80.

RIDGE ROLL.—The cap to the ridge, rounded or splayed, is termed the ridge roll.

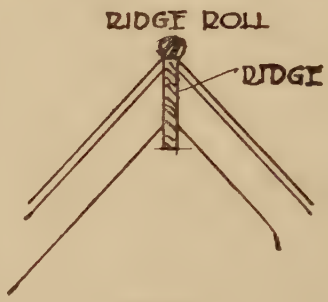


FIG. 81.

WALL PLATES.—Where the feet of the rafters spring from the supporting wall, a timber is run along the length of the wall to take the rafter feet. The rafters may finish on this plate with a V-shaped joint cut in their ends, known as a "birdsmouth," or a V-shaped notch may be cut in their underside and the rafter run over the plate to extend past the outside face of the wall. The rafters are then said to be "notched" on the plate.

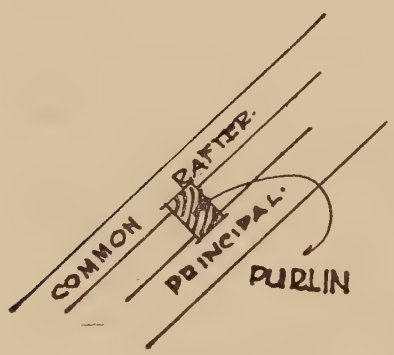


FIG. 82.

PURLINS.—When rafters are of such a length that their own weight and that of the covering upon them would tend to sag them downwards in their middle, a support is run parallel to the walls and generally dividing the rafters from ridge to wall plate in equal divisions. These are known as the purlins.

TRUSSES.—Roofs spanning distances too great for common rafters as above defined unaided, require the additional support of framed structures known as trusses. These consist of king and queen post trusses, the latter being either simple queen post or composite. The spans suitable to each are given in the description of the various trusses.

PRINCIPAL RAFTERS.—The inclined outer portion of the trusses underneath and supporting the purlins are known as principal rafters.

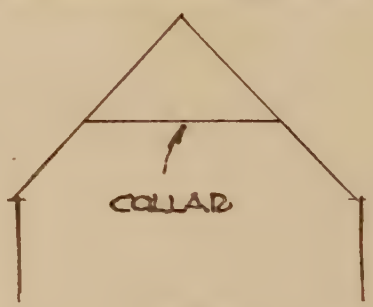


FIG. 83.

STRUTS.—Supporting these principal rafters are struts, springing from straining pieces on the collar or tie or from shoulders on the king post, and at their top end connected to the underside of the principal rafters by means of a butted mortise and tenon.

COLLAR is the name given to that timber stretched from rafter to rafter at right angles to the ridge. The collar may be fixed at any point

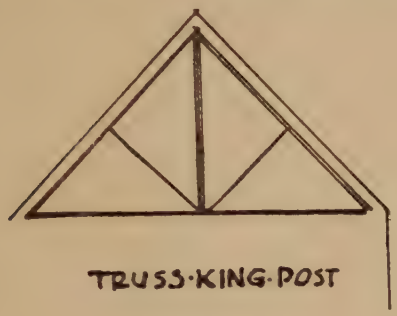


FIG. 84.

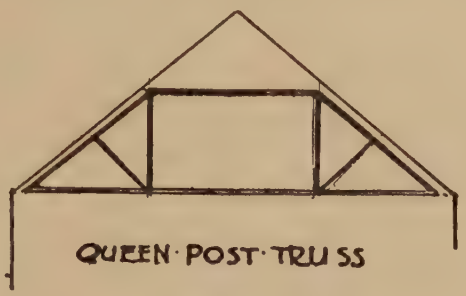


FIG. 85.

in the length of the rafter other than the feet of the rafter, when the roof becomes known as a *collar beam roof*, or it may be fixed to the feet of

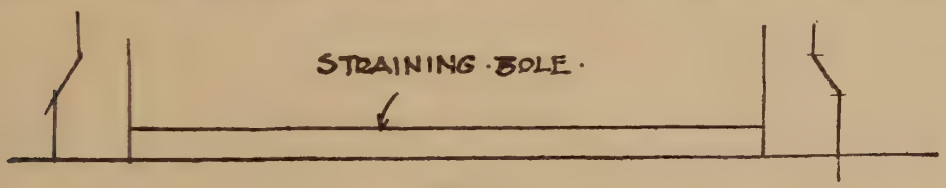


FIG. 86.

the rafter, when it is termed a *tie*, and the roof in its simplest form is known as a *couple close roof*.

KING POST.—For increased spans a support becomes necessary to the centre of the tie. This support, whether of metal or wood, is known as a *king post*.

QUEEN POST.—Where the spans are still greater and it is desired to use the roof space, two supports are introduced at equal distances from the centre of the tie, known as *queen posts*, and the roof truss becomes a queen post truss.

STRAINING SILLS is the name given to horizontal timbers introduced between queen posts to counteract the side thrusts at head and feet of the queen posts.

ASHLARING.—Where room occurs in the roof and the floor area is greater than the horizontal ceiling area, vertical studs are erected from the floor joists to the rafters. These collectively are known as ashlaring.

FIG. 87.

GABLE.—The walls to which the ridge is run at right angles are

continued up to the ridge and to fill in the triangular space made by the rafters. This, though generally of the same material as the rest of the walling, may be framed of timber. The triangular wall is known as a gable.

BARGE BOARDS.—Where either the end rafters are placed on the outer face of the gable wall, or ends of the purlins are run out beyond the gable face, boards are fixed thereto, and to the ridge board at their points of junction. These are known as barge boards.

FINIALS.—To cover the junction of

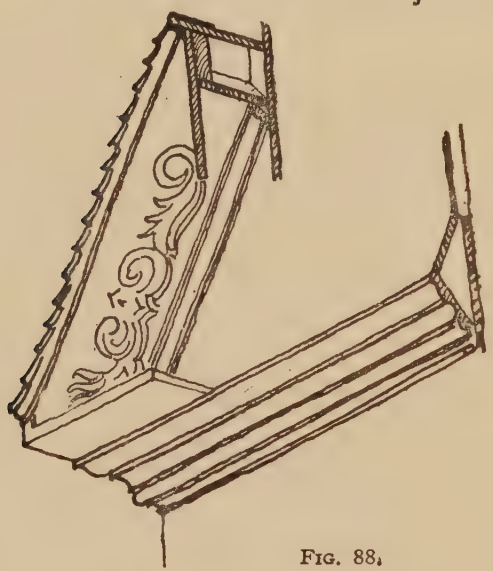


FIG. 88.

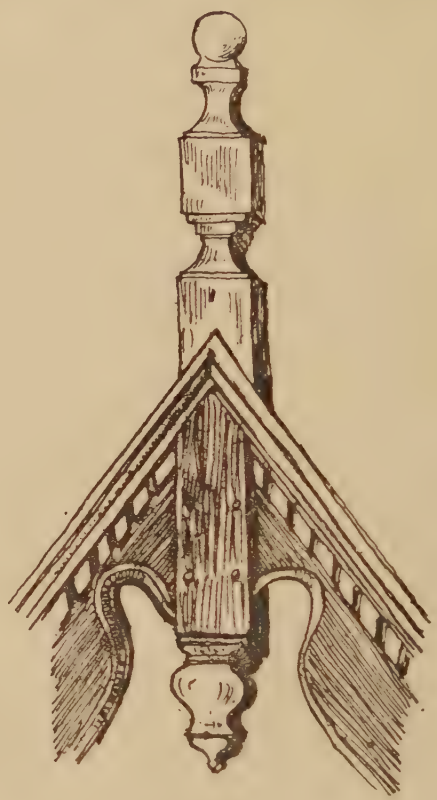


FIG. 89.

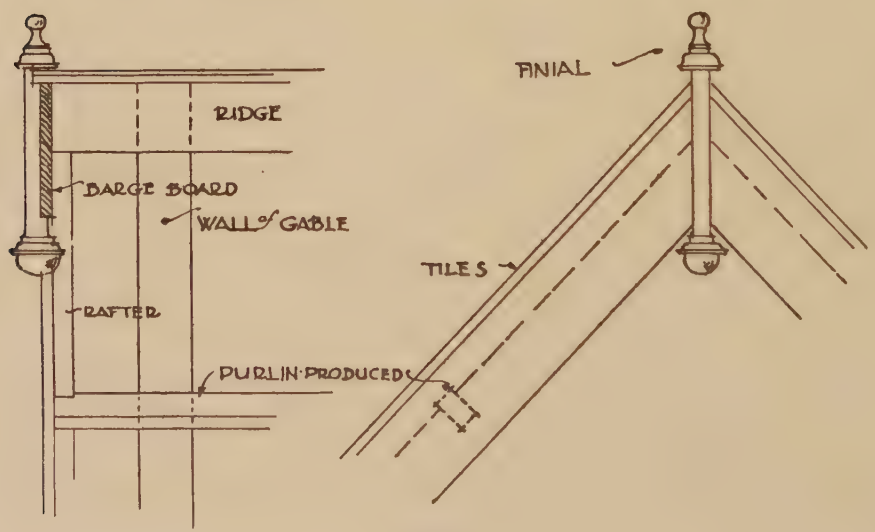


FIG. 90.

the barge boards, and to act as a terminal to the ridge at the ends of the gable apex, a decoration board or pole, often turned circular, is introduced and known as a finial.

VERGE.—This is the name given to the underside of the roof between the barge board where one exists and the face of the gable. Where no barge board exists the name applies to the underside of the part of the roof projecting beyond the face of the gable wall. The verge is sometimes panelled in woodwork, especially where there is a barge board, or it may consist of plain boarding or be simply the underside of the roof covering.

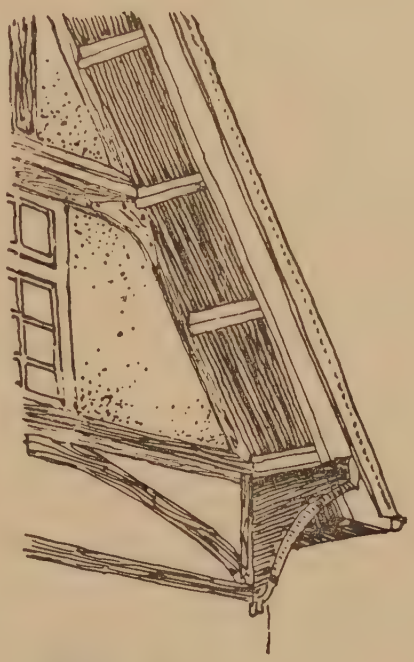


FIG. 91.

EAVES.—Where the rafters project at the feet over the wall face, all that portion projecting is known, in a general sense, as the eaves. Along the bottom of the feet of the rafters is run horizontal boarding which is frequently panelled, but may, of course, be plain. This is termed the eaves soffit.

GUTTER BOARD.—Along the feet of the rafters on their vertical splayed face a board is run to carry the rain-water gutter. This is known as the gutter board or fascia. The latter term having arisen from the fact that in moulded cornices where the eaves soffit is heavily moulded, blocked, and

FIG. 92.

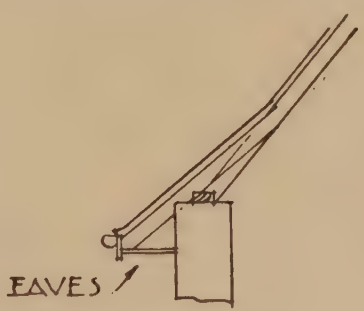


FIG. 93.

bracketed, the gutter forms the cap mould and the gutter board the fascia to the moulded cornice.

SPROCKET.—To slow down the rain-water in its passage down the

roof to the eaves gutter, the pitch of the roof is flattened by means of triangular pieces of wood being fixed to the rafters on their upper sides. These are known as sprocket pieces.

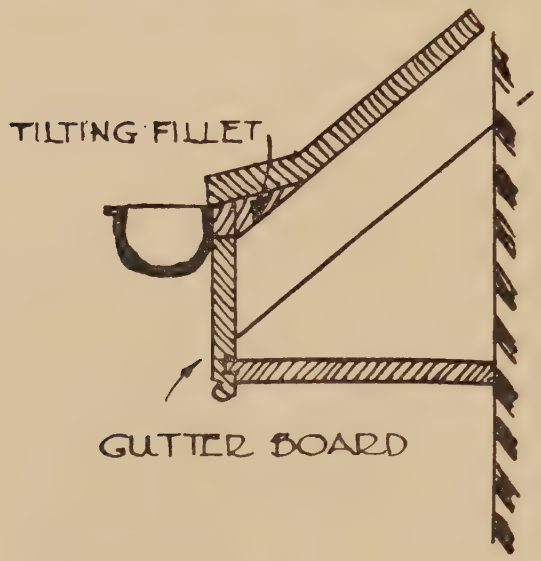


Fig. 94.

Tilting Fillet.—A V-shaped batten run parallel with the gutter board is often made to serve the same purpose as the last, and is known as a tilting fillet. The term is also applied to any bevelled batten used for a similar purpose in any part of the roof.

Battens.—As applying to roofs, this is the name given to the strips of wood fixed over the rafters or roof boarding running parallel to the ridge and used to hang the tiles or slates to.

Hip Roof.—Where, instead of a gable, the end portions of the roof are sloped back to the ridge, as with the sides of the roof, the method is known as a hipped roof, and consists, in heavier work, of a truss fixed at right angles to the last truss, the principal rafter of this truss abutting against the head of the king post of the last truss. Heavier rafters are introduced at the angles and are known as *hip rafters*. In lighter work the hip rafter only is used—the truss being omitted.

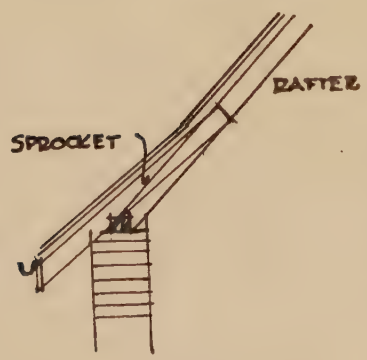


Fig. 95.

A Dragon Tie is the name given to that tie used at the feet of the hip rafters.

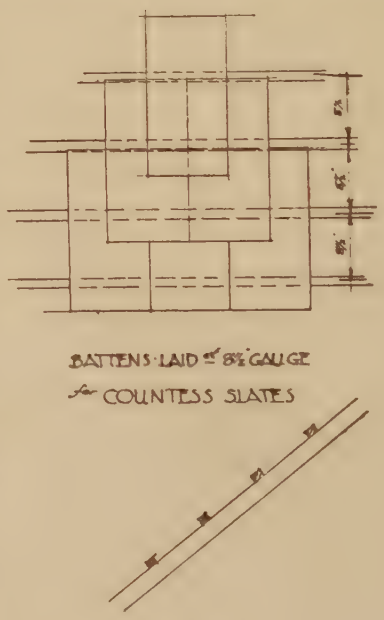


Fig. 96.

Roof Boarding.—In all good work the rafters should be covered with boarding, and this, again, with roofing paper or felt. The felt is sometimes put on under the boarding, as when feather-

edged boarding is used for hanging the tiles to direct—battens being saved thereby. Otherwise flush boarding, butted or V-jointed, is used.

Boarded Runs to Roofs.—Where an attic is otherwise unused, rough boarded runs should be fixed, leading to tanks and other positions it may be desired to have access to.

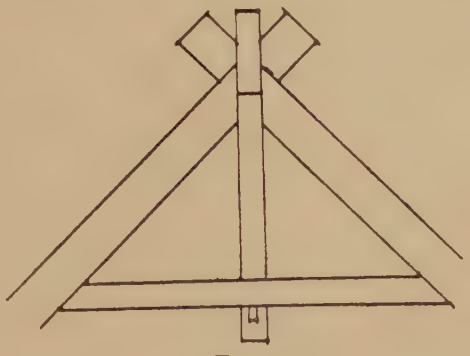


Fig. 97

Flats.—Where flats occur they should be boarded with tongued and grooved boarding, and the rafters under this should be graded to give the flat a slope to the outer edge or towards the gutter.

Lead Rolls.—On these flats for the accommodation of the leadwork and to facilitate its jointing, rolls of rounded egg-shaped section are fixed.

Dormer Windows are those which are cut into the slope of the roof, trimmers being required to take the feet of the rafters cut, and vertical frame work or ashlaring forming the side of dormers. Flat-headed dormers require the rafters to be furred to fall towards outer face. This is done by tacking on to them sloped strips or merely sloping the rafters from the trimmer outwards to the dormer face. Purlins must be cut where they would come across the window ; but skilful design will enable the purlin to be at the same height as the trimmer, so that no cutting and consequent weakening is required.

DRAGON TIE

Fig. 98.

Cross Boom.—Over wide spans where it is not desired to occupy the space in height requisite to form a ridge, the roof is truncated and a flat substituted for the upper portion of the roof. The roof then becomes a trussed purlin roof, and the upper portion of the truss is formed of diagonal ties ; the top member of which forming the flat is known as the *cross boom.*

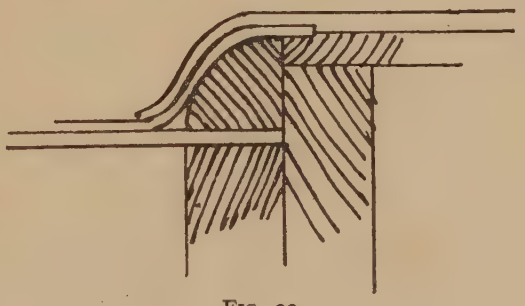


Fig. 99.

Hammer Beam Roof is a form of Gothic roof as seen at Westminster Hall and described elsewhere in detail. The determining detail of the Gothic roof was the internal height which it was desired to obtain. The pitch was steep, and the space interiorly was to be open. To this end a collar was placed high in the structure, and the feet of the rafters tied in, in place of the ordinary tie, by means of a triangular bracket truss

running from the foot of the rafter to meet a vertical support run from the purlin or point of junction of the collar with the rafter. This truss is termed a hammer beam truss.

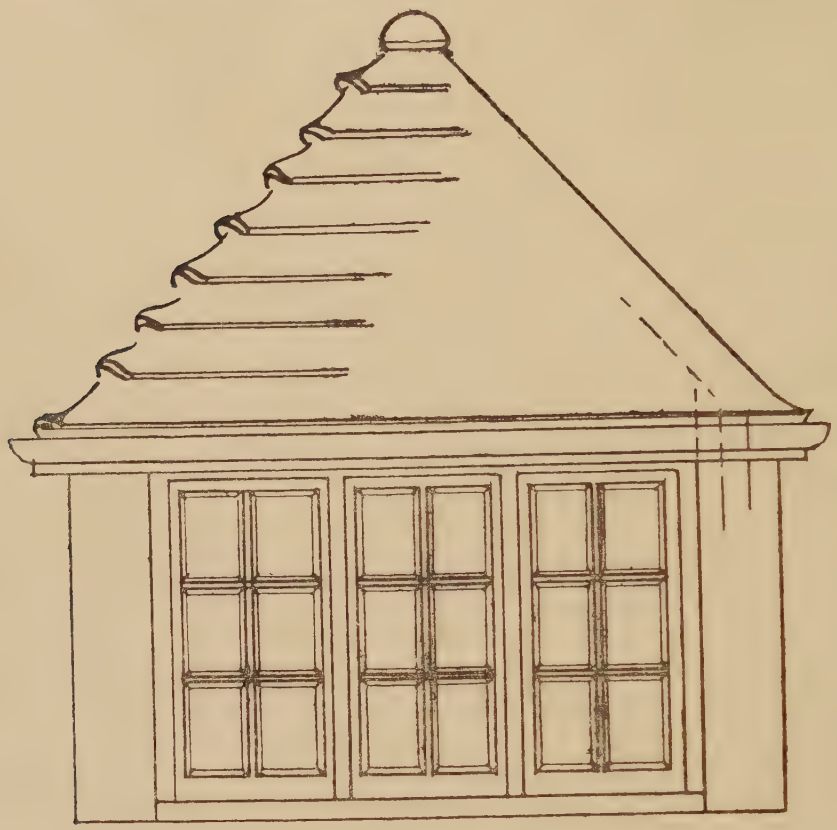


Fig. 100.

The Belfast Truss is composed of a number of thin planks criss-crossed diagonally and nailed together at their point of crossing. They

FIG. 101.

support light purlins for a curved roof, the top member of the truss being double and known as *bows*. The planks are termed lattices, and the component members of the collar, also double, are termed *strings*. These are boxed in the underside by means of a *cover piece*.

The Scissor Beam Truss is another form of roof used where internal height is desired, and in some sense resembles the Gothic roof, though the structure is lighter and more economical. As the name suggests, the rafters cross each other in the manner of the blades of a pair of scissors, the upper portions above the point of crossing forming struts to the upper purlins. The lower portions, being considerably longer, rest on upright struts running from the floor upwards.

Turret Roofs are those framed above circular or octagonal towers.

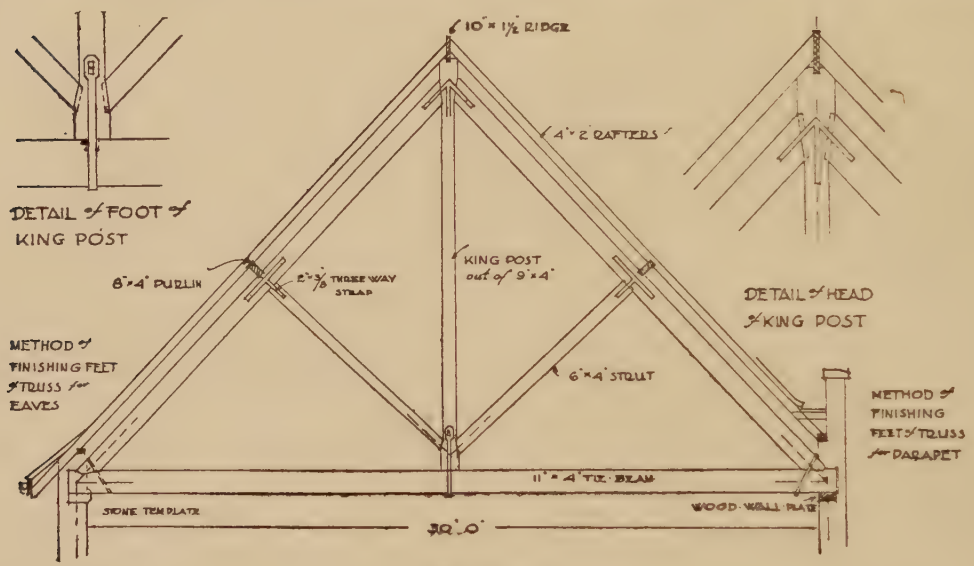

6" × 1½" RIDGE
4" × 2" RAFTERS
DETAIL OF FOOT OF KING POST
8" × 4" PURLIN
2" × ⅜" THREE WAY STRAP
KING POST out of 9" × 4"
DETAIL OF HEAD OF KING POST
METHOD OF FINISHING FEET OF TRUSS for EAVES
6" × 4" STRUT
METHOD OF FINISHING FEET OF TRUSS for PARAPET
11" × 4" TIE BEAM
STONE TEMPLATE
WOOD WALL PLATE
30'0"

Fig. 102.

The structure is framed in the octagonal roof by means of rafters at the angles running from a block at the apex to the lines of junction of the wall plate. Purlins are inserted between these main rafters horizontally, and the common rafters cut in short lengths to fit in between the purlins and the plate at the bottom and block at the top.

Double Span Roofs from 10′ 0″ to 14′ 0″ span are known as *couple-close roofs*, and require a tie run between the feet of the rafters to keep the rafters from spreading outwards. Where the span exceeds 12′ the rafters must be 4½″ by 2¼″, but up to that span 4″ by 2″ will suffice. The tie is jointed to the feet of the rafter by means of a dovetailed halving. And the rafters may be either birdsmouthed on to wall plate or birdsmouthed over to carry the fascia board and gutter. For additional stiffness a binder may be inserted longitudinally in the centre of the ties. The tops of the rafters will be cut splay to butt against the ridge

board and nailed thereto. The tie beams also form the ceiling joists, the latter being nailed directly thereto.

THE COLLAR ROOF.—Arising out of the need for support for rafters at every 8′ 0″ in their length, where the span and the height and consequently the length of the rafter are increased, it becomes necessary to fix the tie at a distance not more than 8′ 0″, measured on the length of the rafter from the ridge downwards. This type is suitable for spans up to 17′ 0″, and gives the additional convenience of enabling the roof span to be used in part.

A MANSARD ROOF

FIG. 103.

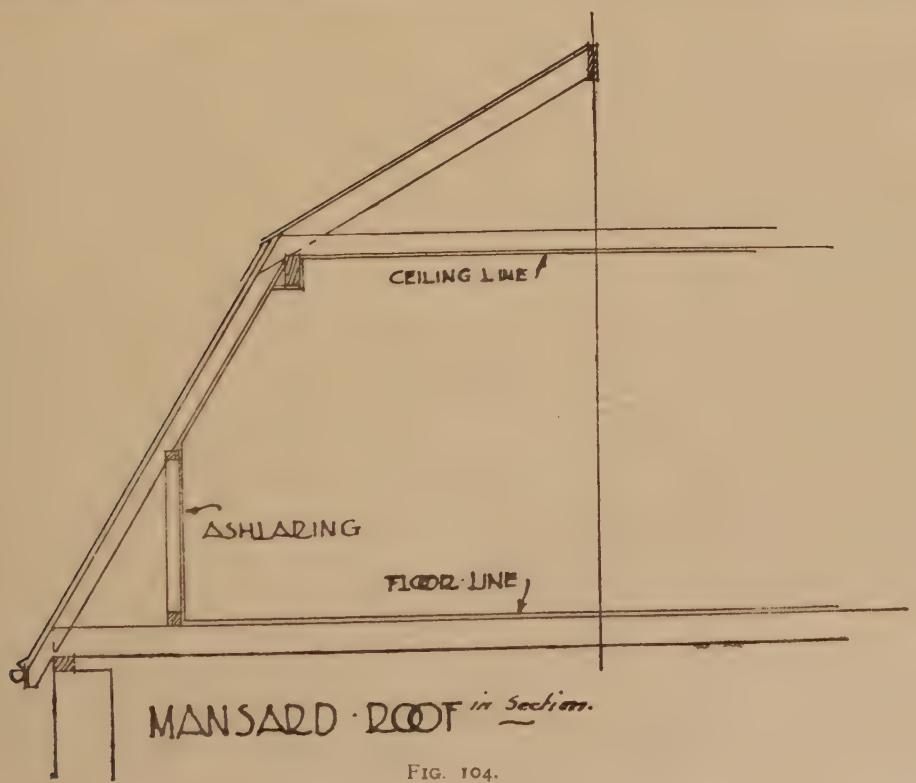


FIG. 104.

It is frequently met with in low buildings, such as farm buildings and in houses where the attic storey is used for habitation.

Though the intention of the collar is in part that it should support the weight of the rafters in their length with the giving of the walls, it becomes in fact a tie tending to bend the rafters, and is to this extent objectionable. To counteract this a tie beam should be added at the level of the springing, thus rendering the collar into a permanent strut. But, of course, this prevents the additional height being obtained.

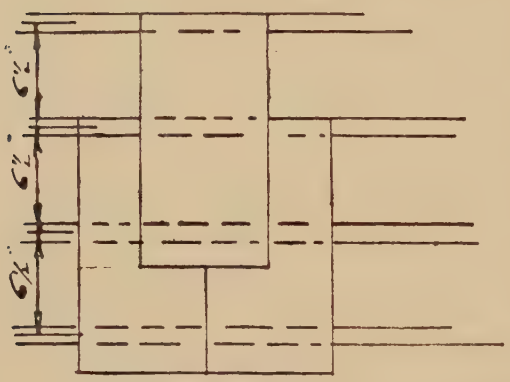


Fig. 105.

A collar roof may also be considerably strengthened, as it frequently is where the attic is in use, by means of vertical studding or ashlaring from about 3′ 6″ to 5′ 6″ in height, running from the floor to a plate under the rafters.

The Mansard.—Another form of roof, and suitable where it is desired to make the most of the space, is that known as the "mansard." The upper portion of this in its simplest form consists of a couple-close roof, the rafters of which rest on purlins which are tied together by the ceiling joists. The lower rafters, being slightly pitched from the vertical, are run from the purlins to the wall plates at the floor level. At the feet of these is generally added a sprocket to throw the water outwards at the bottom.

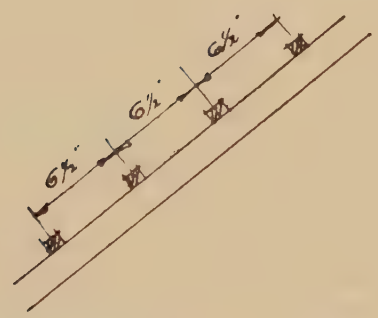


Fig. 106.

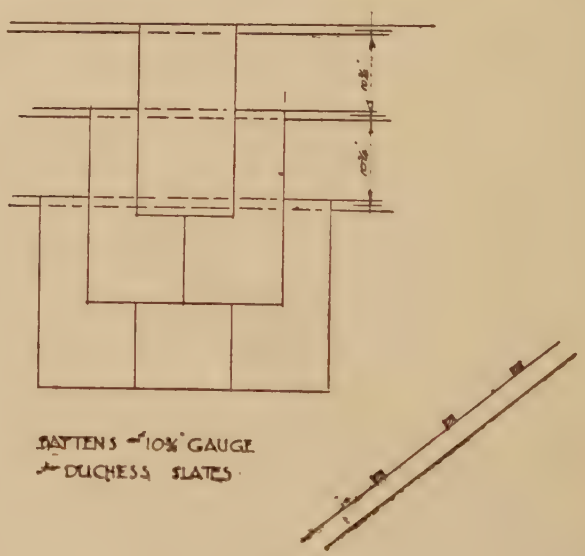


Fig. 107.

Of course, the upper portion of a mansard roof may have either a king post or a queen post truss, as required by the span.

Rules for designing the space required to be roofed with a mansard have been given, but it may be open to doubt if practical considerations of space required for rooms will not be the deciding factor in most cases. One—Belider's—method consists in dividing the circumference of a semi-circle struck with a centre at half the span into four equal parts. That point vertical over the centre becomes the ridge, and the two lower points are the junctions of the lower or true roof and the upper or false roof. But even more than most rules, it will be more honoured in the breach than in the observance.

ANGLES AND WEIGHT OF VARIOUS ROOF COVERINGS

Covering.	Inclination to horizon.	Ratio of rise to span.	Weight of material per foot super.
			lbs.
Tin	5° 43′	1/20	0·7 to 1·25
Lead	5° 43′	1/20	5·0 „ 8·0
Zinc	5° 43′	1/20	1·0 „ 2·0
Copper	7·36	1/15	0·8 „ 1·25
Asphalted Fell	18·26	1/16	0·3 „ 0·4
Slates, large	22·0	1/5	9·0 „ 11·0
Slates, ordinary	26·33	1/4	5·0 „ 9·0
Thin slabs of stone	26·33	1/4	20·0 „ 25·0
Pantiles	26·33	1/4	8·0 „ 12·0
Plain tiles	33·40	1/3	16·0 „ 20·0
Thatch of straw	45·0	1/2	6·0 „ 8·0
Cement-asbestos:			
Bell's standard diagonal tiles	25°–35°	—	Per square, 2¾ cwts.
„ „ sheets	under 30°	—	Per 100 sq. ft., 315 lbs.; per sq. yd., 24 lbs.

Economical Roofs

Where economy is essential and endeavours are made to reduce the scantlings of timbers, some useful hints may be obtained from foreign practice. For instance, the following note from a report issued by the Board of Agriculture on "Buildings for Small Holdings," refers to that land of timber-house construction, Sweden. On page 47 of the Report we read :

"A striking feature in Swedish construction is the light scantling of the roof timbers, even where the span is wide. Many of the Swedish roofs that we saw would certainly not comply with any building bye-laws in force in this country, and apart from the requirements of bye-laws, it may be doubted whether an English architect or builder would venture on a similar type of construction, notwithstanding that it is one that has stood the test of years and the weight of the heavy Swedish snowfall. The following figures illustrate the difference in construction and cost between the English and Swedish roof timbering. The basis of comparison is a smallholder's house in an urban district in the East Riding of Yorkshire, measuring 28′ by 21′ 6″ outside, with 12″ overhanging

eaves and gables ; and it should, perhaps, be mentioned that the Swedish house, with which the comparison is made, was of brick construction :

" (1) To comply with District Council's bye-laws :

	Cubic feet of timber.
Wall plates, 60′ by 4½″ by 3″ . . .	5½
Purlins, 60′ by 9″ by 4″	15
Ridge, 30′ by 7″ by 2″	3
Spars (15″ centres = 50 spars)—	
762′ 6″ by 3″ by 2½″	40
Total. . .	63½

" At 1*s.* 6*d.* per cubic foot = £4 15*s.* 3*d.*, or 15*s.* 9*d.* per 100 square feet covered.

" (2) To conform with Swedish standard :

No wall-plates, purlins or ridge.

Spars (3′ 9″ centres = 18 spars)—

274′ 6″ by 4″ . . . . . 38 cubic feet.

" At 1*s.* 6*d.* per cubic foot = £2 17*s.* 0*d.*, or 9*s.* 6*d.* per 100 square feet covered.

" Ceiling joists, roof-boarding and tiling laths are not taken into account. The prices given are for the timber only, and if labour were to be included, 65 per cent. must be added ; this would increase the difference in cost to £3 3*s.* 9*d.*, or 10*s.* 5*d.* per 100 square feet covered. Moreover, in this example the price and quality of the wood are assumed to be the same in both instances ; but in practice this is not the case.

" Not only in the roof, but throughout the building generally, the wood specified in Sweden is decidedly inferior in quality to what English architects would make a practice of specifying ; furthermore, such wood is very much cheaper than that of similar quality in England. Great care, however, seems to be taken to use only dry and well-seasoned timber. It is evidently considered that, for houses of the type we saw, a cheap class of wood, thoroughly seasoned, serves as well as one of better quality not so well seasoned ; and further, that it is not necessary to expend much labour on finishing off the woodwork."

Simple Rules for Computing Size of Roof Timbers

The rules given in Tredgold for computing the area of the king post in inches, and the breadth, are as follows :

King Post.—*Rule :* Multiply the length of the post in feet by the span of the roof in feet, and the product multiplied by the decimal 0·12 for fir and 0·13 for oak will give the area of the king post in inches. The area divided by the breadth will give the thickness, and the area divided by the thickness will give the breadth.

Area = Length of span × 0·12 for fir or 0·13 for oak.

Breadth in inches $= \frac{\text{Area}}{\text{Depth}}$. Depth $= \frac{\text{Area}}{\text{Breadth}}$.

Queen Posts.—*Rule:* Multiply the length of the queen post in feet by that part of the length of the tie beam it supports, also in feet; the product multiplied by 0·27 for fir and 0·32 for oak will give the area of the queen post in inches. This area divided by the breadth will give the thickness, and by the thickness will give the breadth.

$A = Lp \times 0{\cdot}27$ for fir or 0·32 for oak; p being the length in feet of that part of the tie beam supported by the queen post, generally half the span.

Depth of Tie Beam.—*Rule:* Divide the length of the longest unsupported part by the cube root of the breadth and multiply the quotient by 1·47 for fir and 1·52 for oak. This will give the depth required in inches.

$D = \frac{l}{\sqrt{B}} \times 1{\cdot}47$ or 1·52 for oak; l being the length in feet of the longest unsupported part.

Principal Rafter.—Where a king post is used.

Rule: Multiply the square of the length of the rafter in feet by the span in feet and divide the product by the cube of the thickness; the quotient multiplied by 0·096 will give the depth in inches for fir.

$$D = \frac{L^2S}{B^3} \times 0{\cdot}096 \text{ for fir, where a queen post is used.}$$

Rule: Multiply the square of the length of the rafter in feet by the span in feet, and divide the product by the cube of the thickness in inches; the quotient multiplied by 0·15 will give the depth in inches for fir.

$$D = \frac{L^2S}{B^2} \times 0{\cdot}15 \text{ for fir.}$$

Straining Beam.—The depth should be to the thickness as 10 : 7 as nearly as possible.

Rule: Multiply the square root of the span in feet by the length of the straining beam in feet and extract the square root of the product; this multiplied by 0·9 will give the depth in inches for fir. To find the thickness, multiply the depth by 0·7.

$$D = \sqrt{(L\sqrt{S})} \times 0{\cdot}9 \text{ (fir).} \quad B = 0{\cdot}7D.$$

Struts and Braces.—*Rule:* Multiply the square root of the length of the rafter supported in feet by the length of the brace or strut in feet, and the square root of the product multiplied by 0·8 for fir will give the depth in inches. The depth multiplied by 0·6 will give the breadth.

$$D = \sqrt{(L\sqrt{p})} \times 0{\cdot}8 \text{ (fir).} \quad B = 0{\cdot}6D.$$

p being the length in feet of that part of the principal rafter supported by the strut.

PURLINS.—*Rule :* Multiply the cube root of the length of the purlins in feet by the distance they are apart in feet, and the fourth root of the product will give the depth in inches for fir. The depth multiplied by 0·6 will give the breadth.

$D = \sqrt[4]{L^3C}$ fir or 1·04 for oak.

$B = 0{\cdot}6D$.

C being the distance in feet that the purlins are apart.

COMMON RAFTERS.—*Rule :* Divide the length of the bearing in feet by the cube root of the breadth in inches, and the quotient multiplied by 0·72 for fir, or by 0·74 for oak, will give the depth in inches.

$$D = \frac{L}{B^{\frac{1}{3}}} \times 0{\cdot}72 \text{ for fir or } 0{\cdot}74 \text{ for oak.}$$

When the rafters are 2″ thick :

$$D = 0{\cdot}57\ L \text{ for fir.}$$

TABLE OF SCANTLINGS

Span in feet.		Tie beams.	Principal rafters.	King post.	Queen post.	Small queens.	Straining beams.	Struts.
		inches.	inches.	inches.	inches.	inches.	inches.	inches.
King post roofs.	20	9½ × 4	4 × 4	4 × 4	—	—	—	3½ × 2¼
	22	9½ × 5	5 × 3	5 × 3	—	—	—	3¾ × 2½
	24	10½ × 5	5 × 4	5 × 4	—	—	—	4 × 2½
	26	11½ × 5	5½ × 4	5½ × 4	—	—	—	4½ × 2½
	28	11½ × 6	6 × 4	6 × 4	—	—	—	5 × 2¾
	30	12½ × 6	6 × 4½	6 × 4½	—	—	—	5 × 3
Queen post roofs.	32	10½ × 4½	5 × 4½	—	4½ × 4	—	6¾ × 4½	4 × 2¼
	34	10½ × 5	5½ × 4½	—	4½ × 4½	—	7 × 4½	4 × 2½
	36	11 × 5	6 × 5	—	5 × 4½	—	7 × 5	4½ × 2½
	38	11 × 5½	6½ × 5	—	5 × 5	—	7½ × 5	4½ × 2½
	40	12 × 5½	7 × 5½	—	5 × 5½	—	8½ × 5½	4½ × 2¾
	43	12 × 6	7 × 6	—	6 × 5	—	8½ × 6	4½ × 3
	46	13 × 6	7 × 6	—	6 × 5½	—	8½ × 6	4¾ × 3
Large or small queens.	50	13 × 8	8½ × 6	—	6½ × 6	6 × 4	9 × 6	4½ × 3
	55	14 × 9	8½ × 7	—	7 × 6½	7 × 4	10 × 6	5 × 3
	60	15 × 9	9 × 7	—	7½ × 7	7 × 4	10 × 7	5¼ × 3

SCANTLINGS OF PURLINS

Bearing in feet.	Distance apart in feet.		
	7	8	9
6	6 × 4	6½ × 4	6½ × 4½
7	7 × 4	7½ × 4	7½ × 4½
8	7 × 5	7½ × 5	8½ × 5
9	8½ × 5	8½ × 5½	9 × 5½
10	8½ × 6	9 × 6	9½ × 6
12	10½ × 6½	10½ × 7	11 × 7

SCANTLINGS OF COMMON RAFTERS AT 12″ CENTRES

Bearing not exceeding	Scantling.
6′ . . .	$3\frac{1}{2}'' \times 2\frac{1}{4}''$
8′ . . .	$4'' \times 2\frac{1}{2}''$ or $4\frac{1}{2}'' \times 2\frac{1}{4}''$
10′ . . .	$5'' \times 2\frac{1}{2}''$
12′ . . .	$6\frac{1}{2}'' \times 2\frac{1}{2}''$ or $6'' \times 3''$
14′ . . .	$7\frac{1}{2}'' \times 2\frac{1}{2}''$ or $7'' \times 3''$

QUEEN POST AND PRINCESSES ROOFS

TABLE OF SCANTLINGS FROM 60′ 0″ TO 90′ 0″

Span in feet.	Tie beam.	Queen post.	Princesses.	Principal rafters.	Straining beam.	King post.	Struts.	Purlins.
65	15 × 10½	8 × 7	5 × 3	8 × 7½	10½ × 8	5 × 3	5 × 3½	8½ × 5
70	15 × 11¾	9 × 6½	5 × 3½	9 × 7	10½ × 9	5 × 3½	5 × 4	8½ × 5
75	15 × 13¾	9 × 7½	5 × 4	9 × 8	11¼ × 9	5 × 4	5 × 4½	8¾ × 5
80	16 × 13	9 × 9	6 × 4	10½ × 9	12 × 9	6 × 4	6 × 3½	8¾ × 5½
85	16 × 13½	9½ × 9	6 × 4½	12 × 9	12¾ × 9	6 × 4½	6 × 4	9 × 5½
90	16 × 14	10 × 9¾	6 × 4½	13½ × 10	13 × 10	6 × 4½	6 × 4	9 × 5½

CONSTRUCTION AND JOINTS USED IN ROOFS

Generally

As the joints used in all roofs are the same in principle, it has been thought advisable to describe them in a section apart from those dealing with the various types of roofs. Of the three kinds of joints used in carpentry—lengthening, bearing and connecting—the first will not be met with as a rule, except in connection with wall plates; and, rarely, in ties of excessive length, and then only when otherwise unavoidable.

Lengthening-Lapping

It may be that in roofs of a temporary nature ties and struts will be lengthened. This is done by lapping. The method

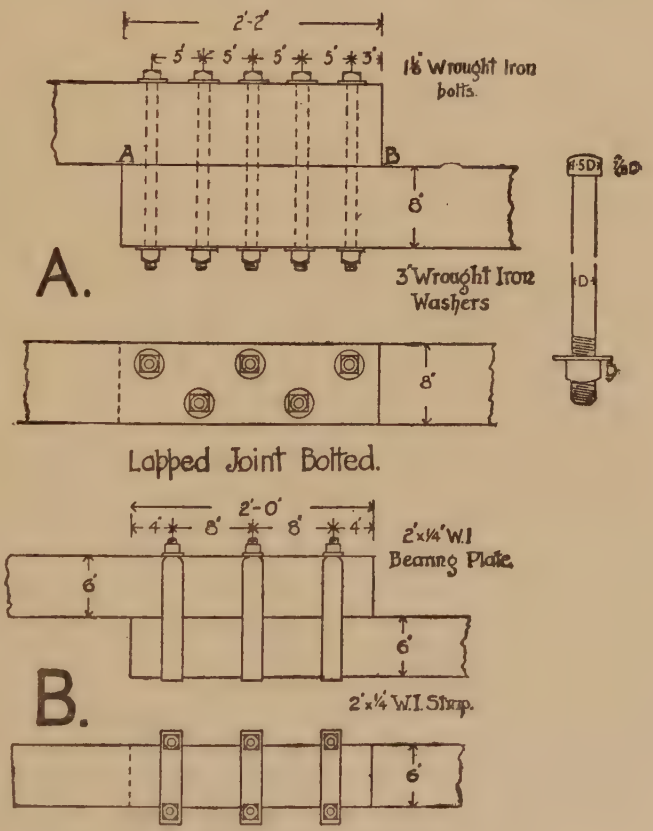
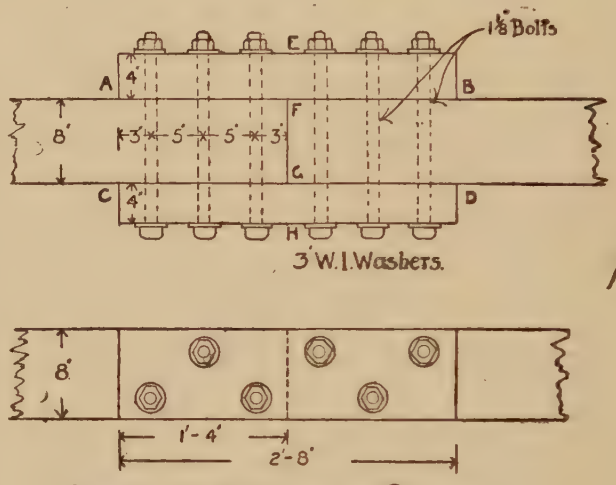


FIG. 108.

is an unsightly one and somewhat elementary in conception, being formed by simply lapping the ends of the two timbers that it is decided to join in their length. These may be lashed together as in scaffolding or they may be nailed, but in better-class work bolts or bolts and straps will be used.

Fishing

Where the timbers are butted at their ends and plates bolted on either side, they are said to be *fished*. The plates may be either of wood or iron, and are termed *fish plates*. The bolts should be staggered in zigzag fashion to prevent undue weakening of the timbers. Whilst in compression, the chief strain will come on the butted ends of the timbers, in tension it will come on the bolts and timber surrounding them, tending to cause the bolts to tear through the timber. The bolts will be loosened from shrinkage of the timbers, thus being caused to press upon the fibres and cause them to yield. To overcome this too great dependence upon the bolts, the fish plates are let into grooves cut in the timbers, as shown at B. The fish plates are then said to be *tabled*. Tabling is performed on only one side, to prevent undue cutting of the timbers. In place of tabling, *keyed* joints may be substituted, as shown in C and D.



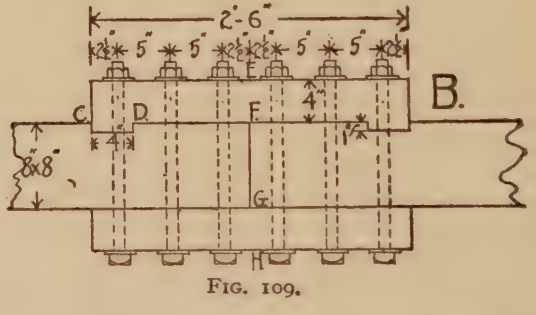


FIG. 109.

LENGTHENING WALL PLATES.—The joints used in lengthening wall plates come more under the heading of legitimate jointing to be met with in roof construction. As there is no tension or compression to be taken into account, the joint consists merely of cutting away one half of the thickness of one wall plate for about 6″ from its end, and fitting the half remaining into the space formed by cutting away the half of the thickness of the other joint. The timbers are then nailed together.

SCARFED WALL PLATES.—Where the cut is made on the bevel, as in the accompanying figure, it is termed a scarfed joint. The theory of the scarfed joint being that it provides resistance to tension, it would not seem that it serves any very special purpose when applied to a wall plate in its length, unless it be resistance at the joint against tension due to shrinkage.

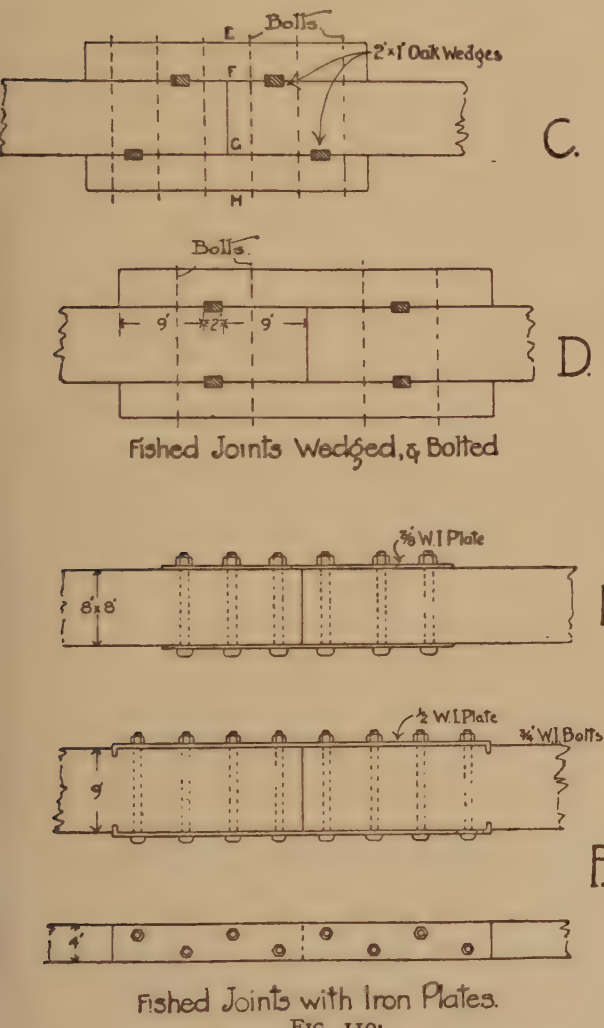


FIG. 110.

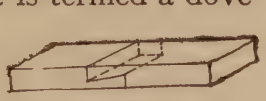
SCARFED RIDGE BOARDS.—Ridges jointed in their length are scarfed and wedged.

WALL PLATE ANGLES AND TRANSVERSE JOINTS. — Wall plates are jointed at their angles by means of a simple halved joint, the timbers being fitted together at right angles, as shown at B, Fig. 112. For greater security, the halving may be bolted as before described.

BEVELLED HALVING.—Where one wall plate is joined to another at right angles in its length, a bevelled halving as at E, Fig. 112, is employed.

DOVETAILING. — This is a form of halving which takes its name from the shape of the tongue and opening cut for the tongue to fit into. Shrinkage of the timbers militates against the use of this form of joint, as it defeats the purpose of its use. The joint is weak at the wedge-shaped shoulders, and to counteract this a *shouldered dovetail* is used.

DOVETAILED NOTCHING.—Where one wall plate crosses another at right angles and extends past the joint, it is termed a dovetailed notch. This joint may also be used at the main angles; the upper wall plates, overlapping for an inch or more, provide a shoulder which prevents slipping from shrinkage.


SCARFED JOINT
FIG. 111.

BEAMS AND PLATES.—The various joints used for supporting beams on wall plates are shown in Fig. 118. That at A indicates

a plain *abutted* joint in which the beam simply rests on the wall plate, being spiked thereto. That shown at B is termed a *notched* joint, consisting of a rectangular cut of $\frac{1}{2}''$ in the underside of the beam to fit over the plate. A more complicated form is shown at E, which is termed a *double-notched* joint, the name arising from the fact that a portion is cut from the plate as well as the beam. In a *housed* joint the end of the beam is let into the wall plate as at F and in crossing as at G, to prevent pulling away from shrinkage or other cause. As shown, the strength of the joint consists in the leaving of a shoulder on the plate to fit into a notch cut in the underside of the beam. Where the beam ends flush with the outer face of the wall plate, the shoulder is on the inner side of the wall plate; whilst

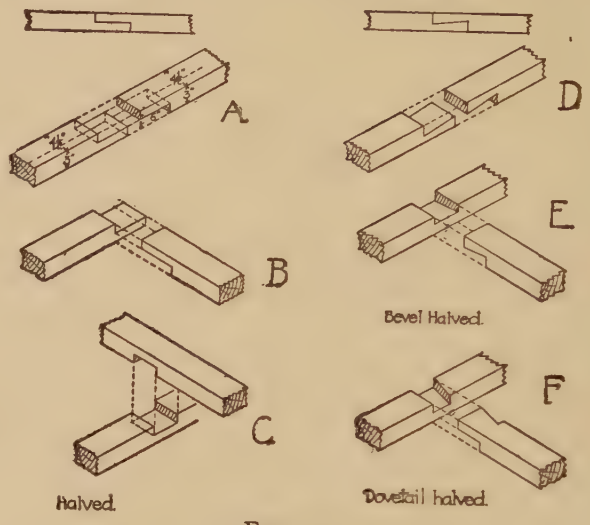


FIG. 112.

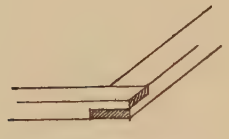


FIG. 113.

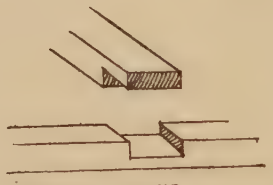


FIG. 114.

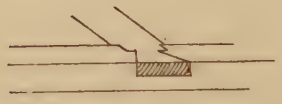


FIG. 115.

where the beam crosses the plate the shoulder is left in the centre of the wall plate, as at K. In skew-cogged joints, the notch is cut at whatever angle is required, as shown at L.

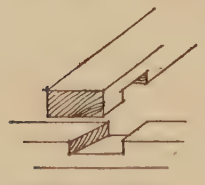


FIG. 116.

Ceiling Beams and Joists

Ceiling joists may be framed to the beam either by *housing*, when the entire end is let into a chase cut in the beam, or a tenon may be cut in the joist to fit into a mortise cut out of the beam. A shoulder may also be left on the lower portion of the end of the ceiling joist to fit over the underside of the beam, whereby, by additional bearing, strength is afforded if the projecting shoulder be nailed.

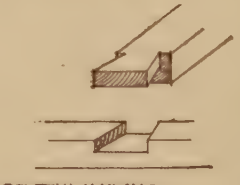


FIG. 117.

CHASE MORTISE.—Where one beam has to be inserted between two beams already fixed in position, or where a rafter is to be inserted similarly, an oblique chase is cut to enable the third timber to be slid into

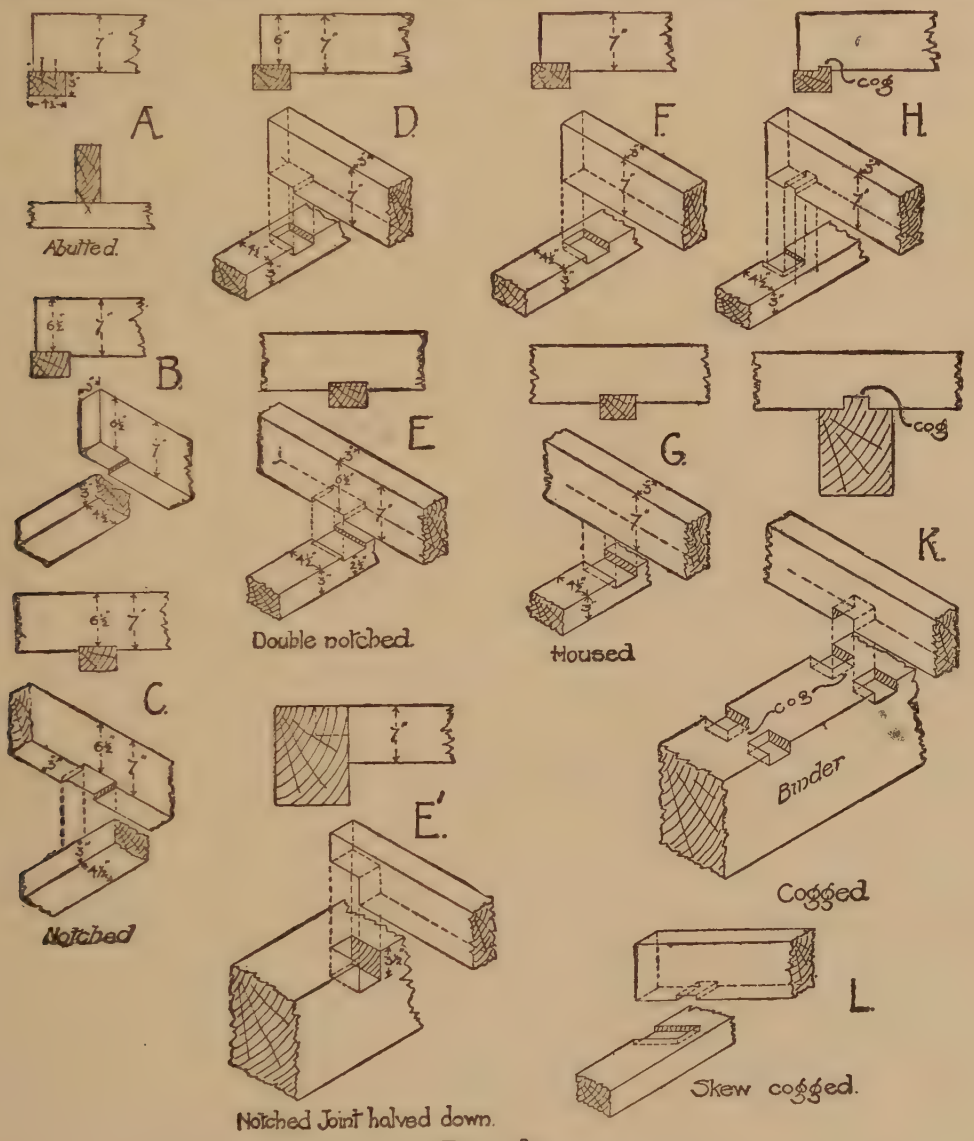


FIG. 118.

position. This operation may be performed either vertically, as at B, or horizontally, as at C in Fig. 119.

Rafters and Plates

BIRDSMOUTH.—Where the rafter feet end on the wall plates, as in Fig. 93, an angular cut is made in the end of the rafter to fit the section

of the wall plate. But when the rafters are run over the wall plate, as is often done to give fixing for the gutter board and gutter, a V-shaped cut is made in the underside of the rafter, as shown in Fig. 80.

However, as this may weaken the rafter if cut too deep, or if a wide overhang is desired, and an undue weight put upon the end of the rafter below the cut in consequence, it will be found preferable if a birdsmouth cleat be strapped to the underside of the rafter, which is thereby left uncut.

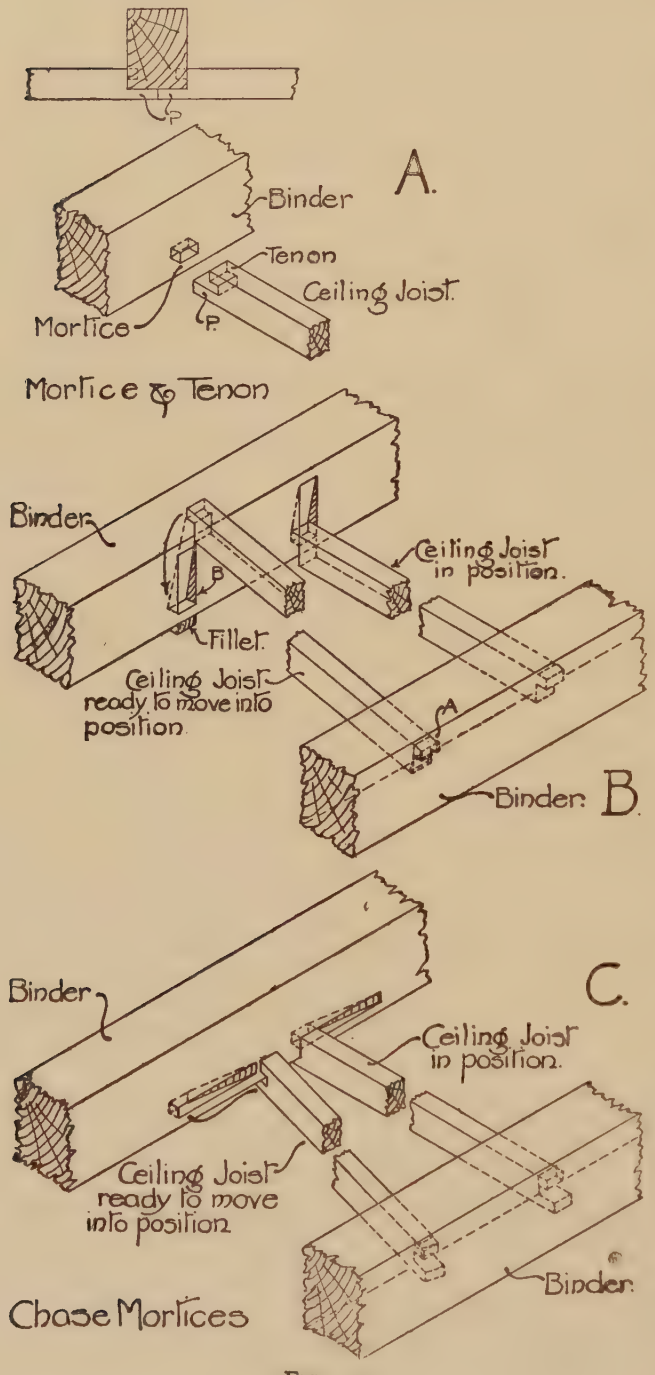


FIG. 119.

Rafters and Ties

ABUTMENT PLATE JOINT.—In heavy work of a rough nature the rafters are jointed to the tie beam by being bevelled on the underside and butted on to an abutment plate bolted to the end of the tie beam, shown in Fig. 120. The foot of the rafter is sometimes pierced also with a bolt as shown. The weakness of this form of joint is the tendency on the part of the abutment plate to shear on account of any sudden too great pressure due to wind.

All the other forms of joints between rafters and ties consist of abutments formed by cutting bevels in the ties.

PLAIN ABUTMENT JOINTS.—In these the rafter feet are bevelled and the tie beam cut to fit the feet as shown at B, Fig. 120. Or where a more economical method is desired, the rafter foot uncut may be let into the groove, but the method is not recommended.

TENONED ABUTMENT.—A more secure fixing is to be achieved by cutting on the bevelled foot of the rafter, as in the plain abutment, a tenon to fit into a mortise in the tie beam, thus giving additional strength in the increased number of bearing surfaces.

The OBLIQUE TENON may be cut with a double abutment as shown; but it is a difficult joint to fix, and it may be questioned whether any great advantage is to be gained from its use. It would prove most useful where the angle of the rafters is a very oblique one.

BRIDLE JOINT.—In this the tenon is cut on the tie beam, and a channel cut in the rafter foot to fit over, as shown at D, Fig. 120.

The BRIDLE JOINT may be constructed as shown at C, Fig. 120, where the mortise extends only across two-thirds of the length of the bevel, the remainder being cut off as a square shoulder. The width of the bridle should not exceed 1/5th of the beam, in order that the cheeks may not be unduly weakened.

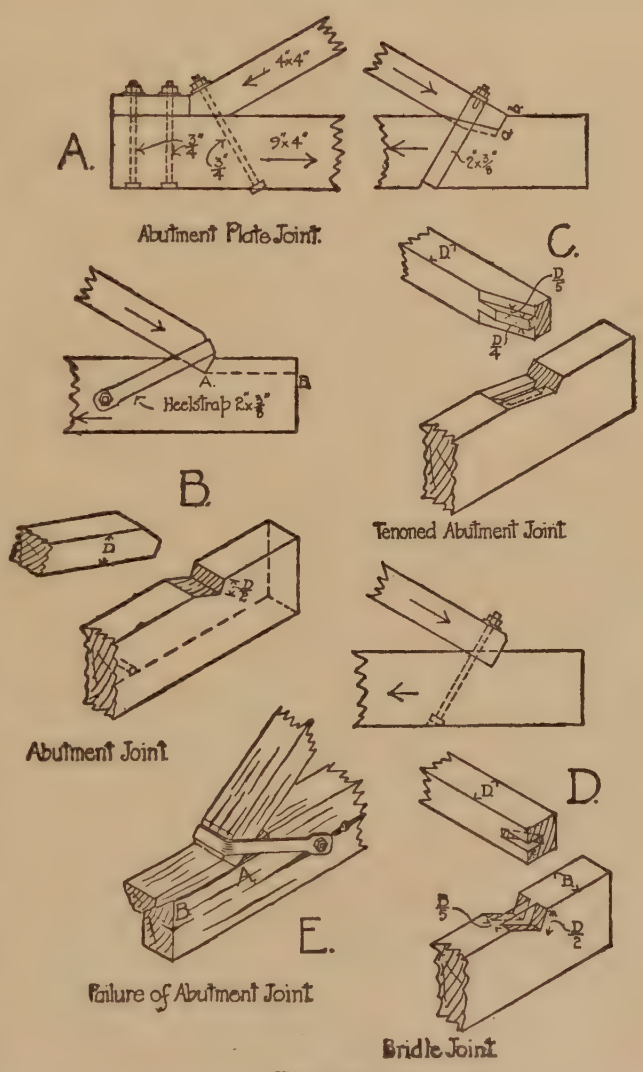


FIG. 120.

STRUT AND BEAM JOINTS.—The essential point in the abutment of the strut against the straining piece is that it should be cut square with the front face of the strut, in order that there may be no tendency to

slide sideways. The joint itself is most suitably a plain mitre, as shown in Fig. 102; and to aid in resistance to any sliding tendency, a cast-iron shoe may be added to receive the ends of the timbers at the angle.

Post and Beam Joints.—The bridle joint, as already described, will be found most satisfactory for this position, but the angular bridle joint is advised in preference to the square, to overcome any inequality in bearing on the shoulders of the tenon.

Tie and Rafter Joints.—The main necessity in the joint between the tie and rafter is that it should be of such a nature as will resist the tension strain upon the tie. Consequently a wedge-shaped notch of dovetail pattern is cut in the half of the thickness of the rafter, and the tie cut to fit, as shown. The tie may be either cut through its entire thickness or halved to fit down flush.

King Post Head and Rafter Joints.—At both the head and foot of the king post a tenon joint is used and the head and foot widened out with a shoulder to take the shoulders of the tenons on the rafters. A square abutment on this widened portion will be found most satisfactory; but where the width will not permit of this, the shoulder may be cut in a Y. The tenon should be made the whole depth of the inclined beam, but in cases where the top of the inclined post is cut off close to the back of the rafter, the tenon is necessarily made narrower in order to leave some wood on the post above it to form a strong upper cheek to the mortise.

An alternative form is that in which the king post is formed in two thicknesses, thus enabling the rafters to pass in between these thicknesses and abut against one another, and underneath a block bolted into a slot cut in the inner sides of the two thicknesses.

The foot of the double thicknessed king post may be treated in the same manner; with the exception that the rafters themselves should be framed into slots cut for their reception in the inner sides of the two thicknesses, the block being omitted, as it is undesirable that any weight should be communicated to the tie beam.

Prevention of Shearing in Abutments

In the abutment joints described above there is the tendency to shear to be guarded against. The safe length of the abutment may be calculated from the following formula, in which X equals the length of the abutment:

R = Safe resistance to shear along X.
T = Tension in tie.
b = Breadth of beam.
S = Ultimate resistance of wood to shear per sq. inch.

$$T = \frac{X \times b \times S}{\text{Factor of safety}}.$$

When $X = \frac{3T}{b \times S}$.

TENSILE COMPRESSION AND SHEARING STRENGTH OF TIMBERS

Description of timber.	Ultimate tensile strength in direction of grain.	Ultimate compression strength in direction of grain.	Ultimate shearing strength.	
			With grain.	Across grain.
SOFT WOODS	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.
Baltic Fir	4,000	5,000	600	—
Cedar	2,900	9,700	—	1,200
Pine, American Yellow	2,300	3,000	375	3,600
Pine, Oregon	—	—	375	2,700
Pine, Kaurie	4,500	5,500	—	—
Pine, Pitch	4,600	6,000	—	—
Pine, American Red	—	—	210	1,500
Spruce	4,000	4,600	270	2,250
HARD WOODS				
Ash, English	3,700	7,000	—	—
Ash, Canadian	5,500	5,500	—	—
Birch	4,800	8,500	—	—
Blue Gum, Australian	5,400	10,000	—	—
Chestnut	8,000	—	375	1,200
Greenheart	9,000	13,000	—	—
Mahogany, Spanish	3,600	5,500	—	—
Oak: English, French, Tuscan, Modeno, Sardinian, American White	7,300	6,000	450	3,000
Ash, Dantzig	4,400	6,600	—	—
Ash, Baltimore	3,800	6,000	—	—
Teak	3,300	9,000	—	—

STRESSES AND STRAINS.—For the better understanding of the reason for the various forms and joints used in roof construction, the following simple description of the stresses and strains to which the various members of a roof are subjected is introduced at this point.

MEMBERS IN COMPRESSION.—All rafters, struts and straining beams are in compression.

MEMBERS IN TENSION.—King posts, queen posts and rods, and all tie beams or tie rods.

MEMBERS UNDER TRANSVERSE STRESS.—Principal rafters loaded by purlins or roof covering along their length between the points at which they are supported. Tie beams carrying ceiling joists.

IN COUPLE ROOFS AND TIES OF COUPLE ROOFS.—Rafters are in compression and the tie in tension.

COLLAR BEAM ROOF.—With firm walls the collar is a strut in compression, but where walls give way it becomes a tie in tension.

KING POST AND ROOFS.—The principal rafters loaded by the roof covering between their points of support are subject to a transverse stress as well as compression. Where the tie beam is loaded with the ceiling it is also subject to transverse stress as well as tension.

QUEEN POST ROOFS.—When the purlins are at the points at which the principal rafter is supported, it is not subject to transverse stress.

CHAPTER III

PATENT MATERIALS—SPECIAL ROOF CONSTRUCTION

Asbestos-Cement Roofing: Corrugated Sheets; Scantlings; Diagonal Tiles; Slates; Pantiles; Roman Tiles; Louvres—Demarcation.

THERE are no doubt both advantages and disadvantages in the use of any of the new materials invented to take the place of the more usually accepted tiles and slates as roof coverings. But these merits or demerits of the materials themselves are not within the scope of the present work. However, there is a point in connection with them which does affect the carpenter. This is the type of roofconstruction which they render possible, for with the majority of the new inventions, being lighter than slates and tiles, the roof timbers

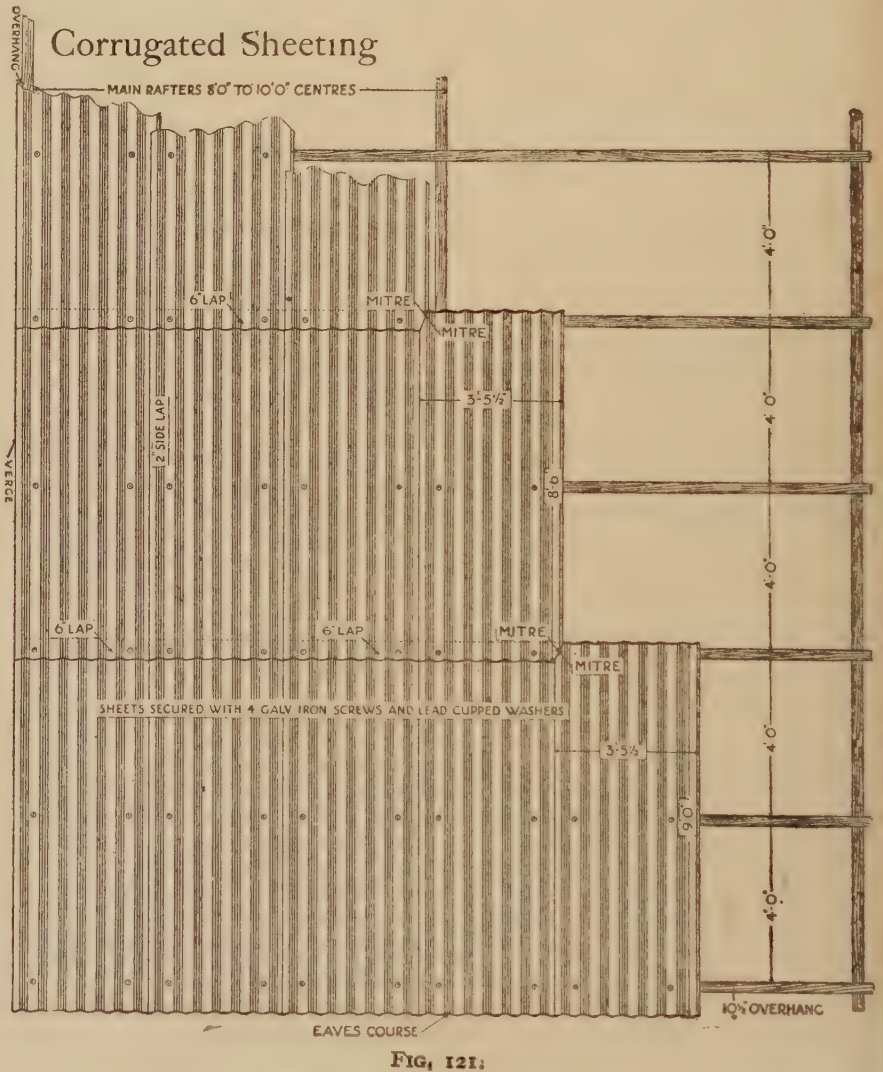


FIG. 121.

required are themselves lighter in structure and less expensive to erect.

Asbestos-Cement Roofing

Corrugated Sheeting for Factories, etc.—These sheets being 9′ 0″ in length by 3′ 6″ in width, the main rafters may be fixed at from 8′ 0″ to 10′ 0″ apart, and the cross battens 4′ 0″ apart, as shown in Fig. 121. The considerable reduction in roof timbering will at once be evident; and on a large building it will be an item very necessary to be taken into account. The actual sizes of the timbers will, of course, be determined by the span and subject to the same rules as have been given for other materials.

Corrugated Sheeting for Smaller Buildings.—Corrugated sheets of smaller dimensions suitable for smaller roofs, such as those for cow barns and other out-buildings, being in size 10′ 0″ by 2′ 6″, permit of the main rafters being spaced at from 8′ 0″ to 10′ 0″ apart, with battens or purlins every 3′ 0″ horizontally. The sizes recommended for purlins and principals are given in table on following page.

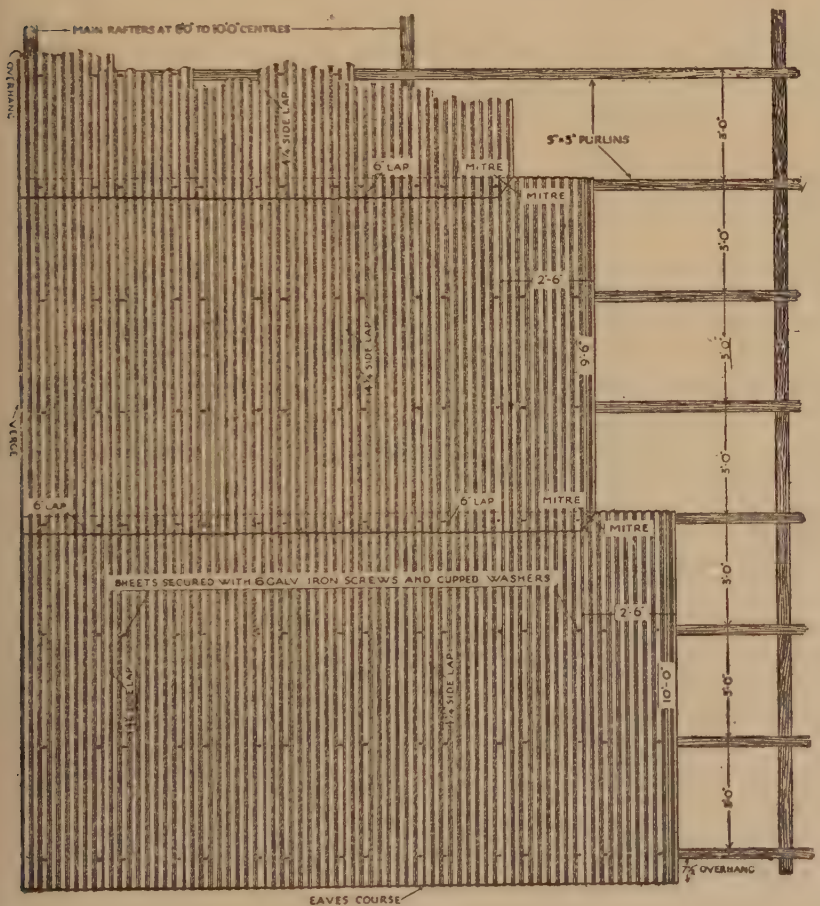


Fig 122.

The weight per square yard of this sheeting is about 24 lbs.; and the weight per 100 square feet of roofing is about 315 lbs. Thirteen square yards of sheeting will be found sufficient to cover 100 square feet of roof.

SCANTLINGS

	6′ 0″	10′ 0″	12′ 0″	14′ 0″	16′ 0″
Centre of principal rafters .	2″ × 2″ × ¼″	3″ × 3″ × ¼″	4″ × 2½″ × ⅝″	4″ × 3″ × ⅜″	5″ × 3″ × ½″
Angle-iron purlins . . .	4″ × 3″	5″ × 3″	6″ × 3″	7″ × 3″	8″ × 3″
Wood purlins . . .					

ASBESTOS-CEMENT DIAGONAL TILES.—Concerning these tiles the following points of advice from the makers, Messrs. Bells, Poilite & Everite Co., Ltd., in so far as they prove of assistance to the carpenter, are here introduced. The tiles, measuring 15¾″ by 15¾″, are made in two varieties, viz. the standard (or C4) pattern and the honeycomb (or F5) pattern, Fig. 126. The former, when laid, show diagonal lines on the roof, while the latter, owing to the bottom point being cut off, produce a design of honeycomb form. Poilite Standard Tiles may be laid either on close boarding or battens, the method of fixing being given in the accompanying illustrations. The lap ordinarily given is 2¾″, but a greater lap is required in exposed positions and where the roof is of the flatter pitch of 35°. (Whether the material is suitable for a flatter pitch, experience will no doubt tell; but the lightness of its nature might seem to suggest that it would not be very satisfactory.) The verges should be finished with a cement fillet. The Standard Tile can be laid to any of the following laps:

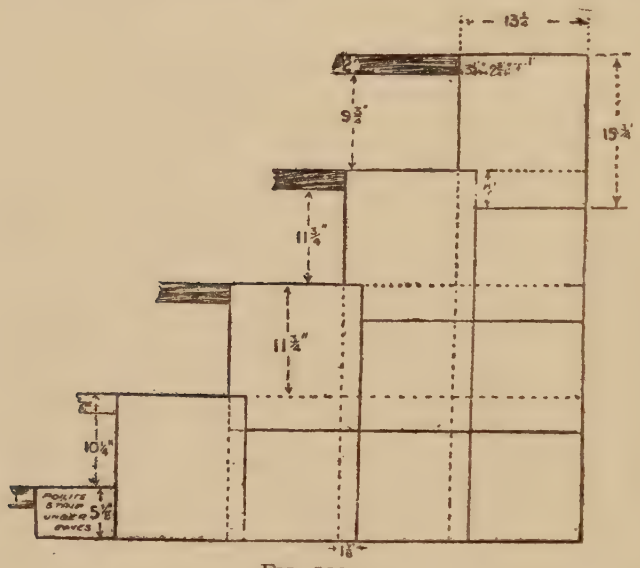


FIG. 123.

Pitch.	Minimum lap.	Tiles per square, net.	Do., including eaves and cuttings.
35°	2¾″	85	88 to 90
33°	3″	89	92 „ 94
30°	3½″	97	100 „ 102
25°	4″	105	108 „ 110

When laid to a 3½″ or 4″ lap, the point of the tile should be cut off,

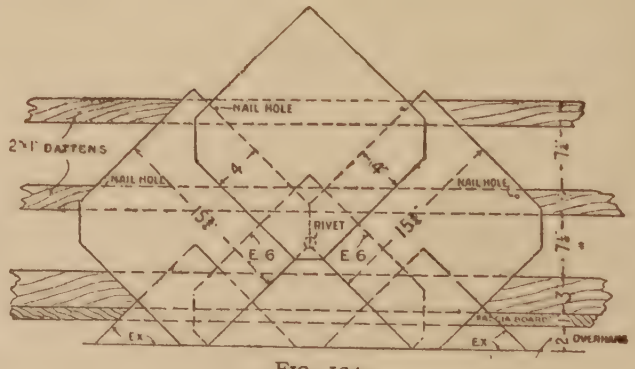
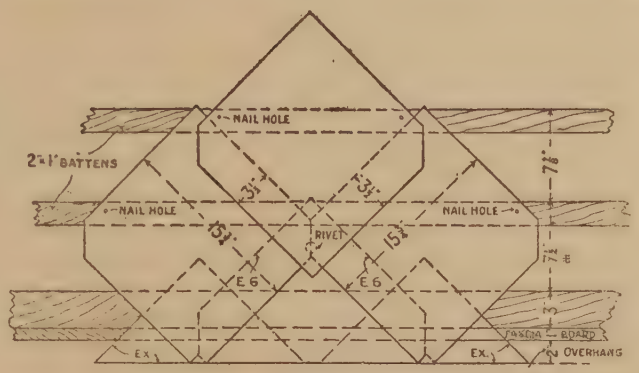


FIG. 124.

otherwise the overhang being excessive would render the lip liable to breakage.

The eaves course is formed by cutting whole tiles so as to produce tiles of the shapes shown in Fig. 125. This is done by scoring with a chisel and breaking off. This is much after the manner that glass is scored and broken. The smaller portion of the tile forms the under-eaves course, and is fixed with a 2″ overhang. On these the upper portion is laid, the two courses being flush at the bottom edges and breaking joint.



No scale. Reduced one-third.

FIG. 125.

FIG. 126.

The copper disc-rivet is placed in the centre of the smaller portion, its shank passing up between the shoulders of the two adjoining larger portions. When the double eaves are thus completed, the whole tile courses are laid, the shanks of the rivets passing through their rivet holes and being flattened down with a tap of the hammer, thus firmly fixing the lower portions of the tiles.

The makers recommend for use in exposed situations, or for a pitch of less than 30°, an underlining of roofing felt, which is supplied in rolls of 24 yards by 1 yard.

One thousand tiles weigh about 27½ cwts., and a square of roofing laid to 2¾″ lap weighs about 260 lbs. A smaller size of this pattern of tile, measuring 11¾″ by 11¾″, can be obtained for use on smaller roofs. It is holed for 2¾″ lap, and the net number of tiles required for a square of roofing is 177.

A square of roofing with Standard Tiles laid to a 2¾″ lap with rafters at 30″ centres and battens at 9″ centres will require 50′ run of rafters and 130′ run of battens.

The accompanying illustrations show the methods of fixing and the spacing of timbers necessitated. The matter has been gone into with some thoroughness, as in many parts of the

country, where such roofing will be mostly used, the carpenter is required to do the fixing also.

ASBESTOS-CEMENT SLATES WITH SQUARE FINISH.—There is to many a prejudice against the diagonal pattern, and for these a slate with a square finish, with or without chamfered corners, has been designed. They are made in grey, slate-blue, terra-cotta and russet-brown colours, and are of the following sizes: 24″ by 12″, 15¾″ by 15¾″, and 15¾″ by 7⅞″. The slate should be hung with two 1¼″ nails, 12 B.W.G. (11 gauge for the 24″ by 12″, or when the site is exceptionally exposed), and a copper disc-rivet, passed up through the joint of the slates under, holds down the bottom edge of the slate as shown in Figs. 123 and 127.

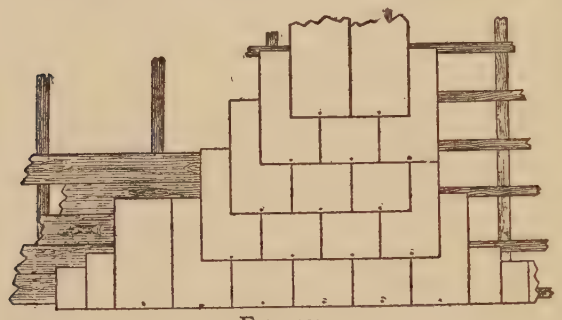


FIG. 127.

A double course should be fixed at the eaves, the size of the eave slate in the case of the 24″ by 12″ being 10½″ by 12″, and 13½″ by 12″, both being cut from the same whole slate by scoring and breaking over a straight edge.

MATERIALS FOR ONE SQUARE OF ROOFING FOR SQUARE FINISH SLATES

Lap.	Size of slate.	Distance of laths or battens from centre to centre.	Foot run of lath.	No. of slates per square.	No. of slates per square, including cuttings.
3″	24″ × 12″	10½″	115	115	120
2¾″	15¾″ × 15¾″	6½″	185	140	147
2¾″	15¾″ × 7⅞″	6½″	185	280	294

Weight per square of slates on roof, 4 cwts.

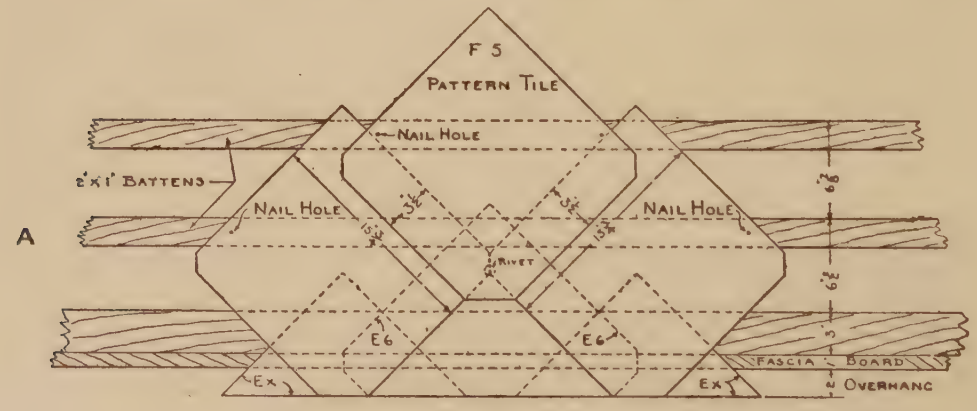


FIG. 128.

Asbestos-Cement Pantiles.—These, of the design shown in Fig. 135, measure 15¾″ by 13¼″ and give an actual cover of 11¾″ by 11⅜″; thus the number of tiles required per square, net, is 108, and the number required, including eaves and cuttings, 111 to 113. One thousand tiles weigh about 29 cwts. A square of roofing laid to 4″ lap weighs about 362 lbs.

The pitch of the roof should not be less than 40°, unless boarding or felt is used under the tiles, when a pitch of 30° can be used, but if the site is particularly exposed, felt should always be used.

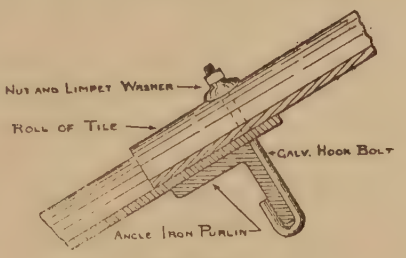


Fig. 129.

The tiles should be fixed to strong battens with two 1½″ galvanised nails. The second nail which is just off the bearing of the tile on the batten, should be driven far enough to cause the roll of the tile to bind on the next tile under, but not so as to cause the tile to crack. To give a solid effect and strength to the eaves, the strip shown in Fig. 130 should be used, and the roll of the tile pointed in with cement and sand. To ensure this holding in position, a strip of wire-netting may be fixed on the top of the strip; and this strip is also recommended on both sides of the valleys. It should be noted that 4″ flat-headed nails are required for fixing cut tiles on the right-hand side of the hips and valleys. If there is no eaves soffit-boarding, it will be necessary to bed up the roll of the tile where it passes over the beam-filling to prevent vermin penetrating into the roof. The tiles are easily cut where necessary with a good hack saw. For hipped roofs these tiles are particularly suitable. Where there are gables, special double roll verge tiles are supplied, to enable the two verges to match. Hips and ridges for use with these tiles should be either 9″ diameter half-round clay tiles or special heavy half-round asbestos-cement tiles can be obtained in 15¾″ lengths. To obtain a satisfactory adhesion of the bedding under hips and ridges, this should be of 1 to 3 cement and sand, used fresh. Ridge and hip timbers should be kept 2″ above battens or board; and hip

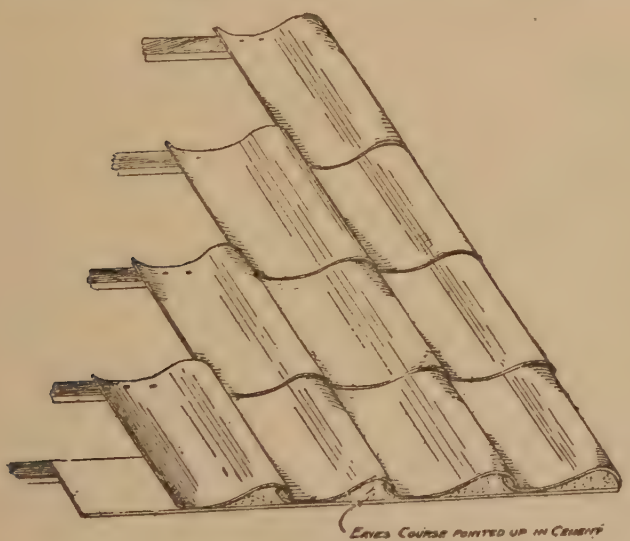


Fig 130.

irons should always be used. The method of fixing and spacing of

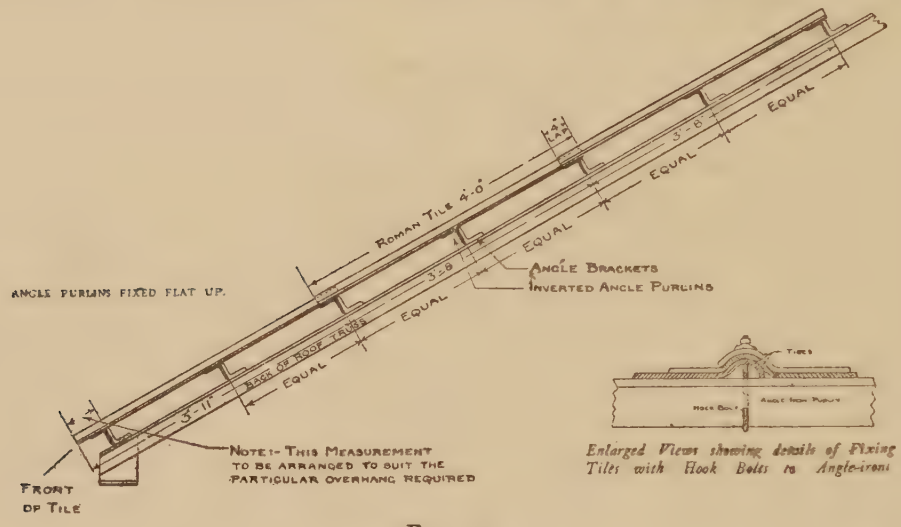


FIG. 131

battens required is shown in the accompanying illustrations. The tiles may be obtained in grey or russet-brown colour.

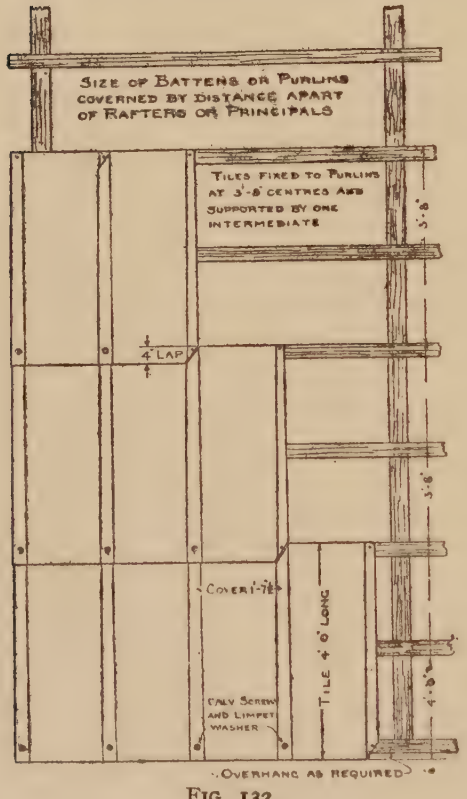
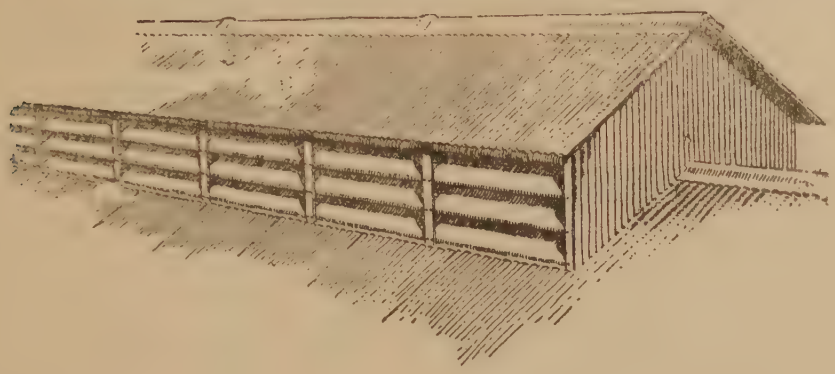

SIZE OF BATTENS OR PURLINS COVERNED BY DISTANCE APART OF RAFTERS OR PRINCIPALS
TILES FIXED TO PURLINS AT 3'-8" CENTRES AND SUPPORTED BY ONE INTERMEDIATE
3'-8"
4" LAP
3'-8"
COVER 1'-7½"
TILE 4'-0" LONG
4'-0"
GALV SCREW AND LIMPET WASHER
OVERHANG AS REQUIRED

FIG. 132.

ASBESTOS-CEMENT ROMAN TILES may be obtained in grey or russet-brown and are suitable for roofs of 35° pitch and steeper. The size is 4′ 0″ by 1′ 8¼″ and the net cover 3′ 8″ by 1′ 7½″. Seventeen tiles should be allowed for 100 square feet of roofing. These tiles will be found suitable for the roofs of factories and engineering buildings, railways, sheds, etc. The method of fixing and the timbers required and their spacing are shown in Fig. 131, and it should be noted that the two top angles should be fixed about 1″ down on either side of the apex in order that the ridges may be secured thereto. Roman tiles should be secured by two 3″ wood screws and cupped washers fixed through the rolls of the tiles. The holes for the screws should be drilled 1/16th larger than the largest part of the diameter of the screw, and on no account should these be made with the slater's pick.

Asbestos-Cement Louvres.—In certain types of building where fireproof materials are especially desirable, portions usually constructed



PERSPECTIVE VIEW showing POILITE LOUVRES

Fig. 133.

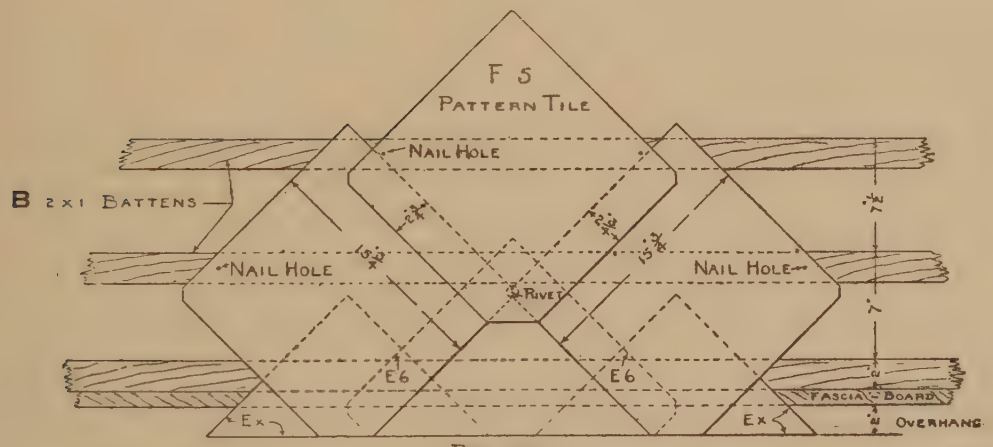
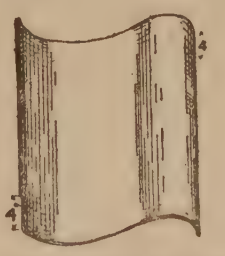


Fig. 134.

in wood are giving place to asbestos-cement. This applies particularly to ventilating louvres used on the roofs of fireproof buildings, also on buildings, such as gasworks, where louvres of wood or metal would rapidly deteriorate from the gases in the air. These asbestos-cement louvres are supplied in 4′ 0″ lengths, and if desired can be drilled ready for attaching to upright standards with bolts or screws. For an efficient fixing, these standards, of either metal or wood, should be arranged at the junction of each length of louvre, and should support the same both inside and out. Alternatively the louvres may be bolted to cleats



DETAIL SHOWING NOTCHING

Fig. 135.

on the sides of standards at each end of the louvre length, or a third method of fixing sometimes adopted is to cut a notch with the saw in the corner of the louvre, which is then slipped into a slot in the timber uprights.

As the carpenter is often required to fix the above, the matter is here introduced and gone into in detail. The accompanying illustrations show their use and method of fixing.

Demarcation

Concerning the matter of demarcation and the trades to which the

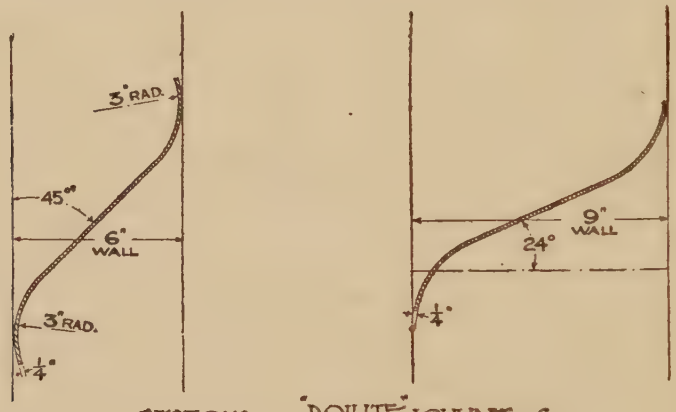


Fig. 136.

duty of fixing newly invented materials belongs, a word may not be out of place at this point as applying *à propos* asbestos cement. Where the new invention replaces woodwork, there would seem to be little difficulty in determining by whom the fixing should be done. But where, as in roof coverings, it replaces the tiler's or slater's customary work, these tradesmen would seem to have a reasonable claim to the fixing. But on the nature of the new material a good deal must necessarily depend, and where any new material, such as asbestos-cement, is cut and fixed with the tools of the carpenter, it must be recognised that the carpenter's claim to fix is the only reasonable one.

CHAPTER IV

WESTMINSTER HALL ROOF

By William Harvey

Gold Medallist and Travelling Student in Architecture, School of Royal Academy; Owen Jones Student; Late of H.M. Office of Works; Author of "The Preservation of St. Paul's Cathedral and Other Famous Buildings"

In size and age and artistic style the oak roof of Westminster Hall ranks as a notable historic building, and the interest of its archæological aspect is by no means diminished by the extraordinary structural devices employed in its design and erection.

The great span of William Rufus's old Norman Hall places the construction outside the common run of carpentry works, for, even when roofed, as it originally was, with intermediate posts or piers dividing the floor into a nave and two side aisles, the beams required to bridge the 69′ from wall to wall must necessarily have been extremely heavy timbers. When Richard II determined to repair the hall, and provide it with a new roof in a single span without intermediate supports, his majestic whim imposed upon the designers of his day an altogether unusual burden, and the scheme devised for its execution involved the assembling of quantities of English oak timber, such as had probably never been gathered together before, and such as it would be altogether impossible to collect at the present time.

Even in those days of royal forests the dimensions of the individual posts overtaxed the resources of the forester. To provide the twenty-six hammer-posts each from a single piece of English oak proved impossible, and one of them had to be eked out with a splice to lengthen it sufficiently to provide a small stub-tenon at its junction with the great collar.

How the foresters were directed in their search for great trees would be an interesting thing to know. In the case of these hammer posts, balks 2′ 3″ square and 22′ long were required, and in addition to their 22′ length of square timber, each post must possess a branch at exactly the right height to form the seating for the upper curved strut. This branch brings out the total width to 3′ 6″ at a point 11′ from the butt of the log. The main collars of the thirteen trusses, although built of two whole timbers placed side by side, are still great sticks 40′ long and 2′ 3″ deep in the centre of their length. Each of these collars had to

be cut from a log that would permit of an upward camber of 9″ on its underside and 1′ 6″ on top, the balks being fashioned with their greatest depth in the centre of the span.

FIG. 138.

One of the minor interests of the Hall is the number of curious fables that have grown up in connection with the building. Until a microscopic investigation demonstrated the material of the roof to be English oak, a common tradition asserted that the timber had been imported from Ireland, and patriotic Irishmen have pointed to the long enduring roof as an example of the superiority of Irish oak and its immunity from the attacks of insect pests. A similar and equally erroneous assumption that the freedom of the timbers from the attacks of insects was due to the use of chestnut wood in the construction proved wrong in both respects, since the roof is not made of chestnut, and has been brought to the verge of collapse by the ravages of *Xestobium tessellatum* — the death watch beetle of popular legend. It is possible that Richard II's Irish war and the confusion between the names of Kingston (on Thames) and Kingstown near Dublin may have had something to do with the Irish oak theory, while the assumption that the roof was made of chestnut wood is almost certainly due to the rich chestnut colour of the timber surfaces.

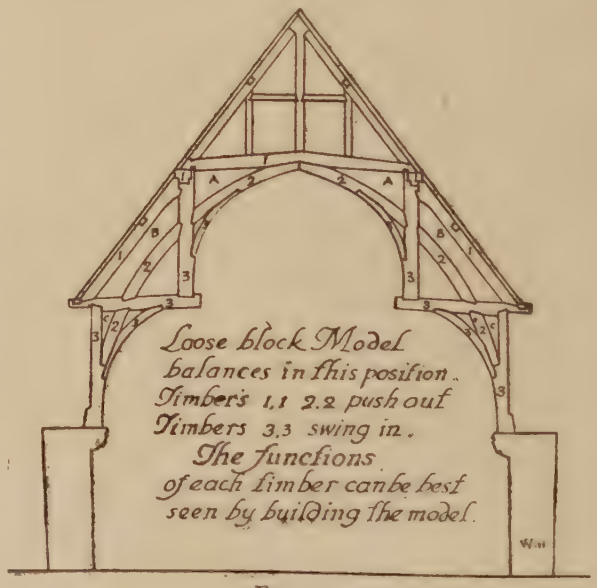


FIG. 139.

This very beautiful warm orange brown is now ascribed to a superficial fungoid decay which has penetrated some 1/16th of an inch into the wood fibres.

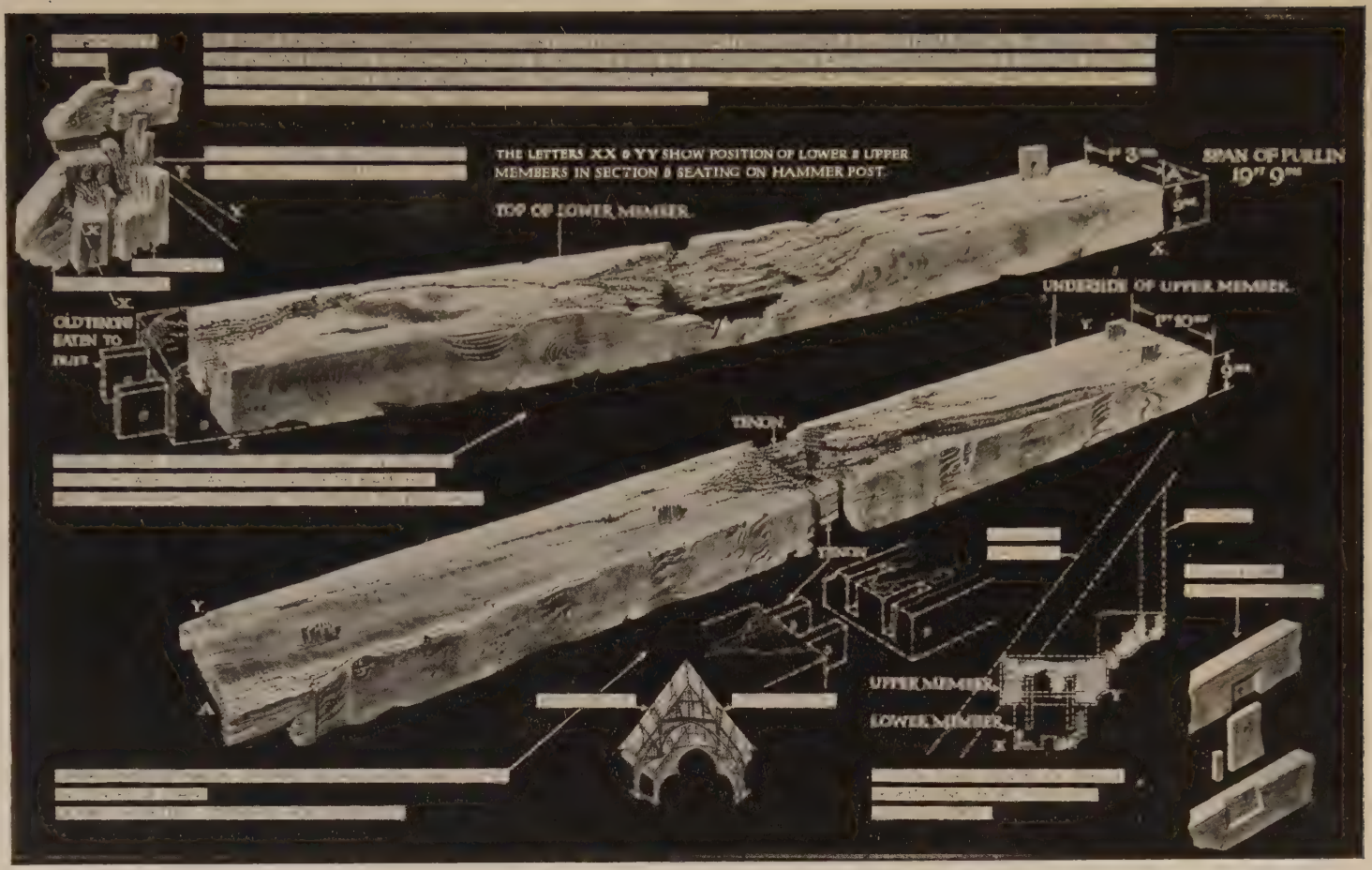

THE LETTERS XX & YY SHOW POSITION OF LOWER & UPPER MEMBERS IN SECTION & SEATING ON HAMMER POST.
TOP OF LOWER MEMBER.
SPAN OF PURLIN 19" 9"
UNDERSIDE OF UPPER MEMBER.
OLD TENON EATEN TO DUST
TENON
TENON
UPPER MEMBER.
LOWER MEMBER.

FIG. 137.—DECAYED TIMBER FROM ROOF OF WESTMINSTER HALL, WITH SECTION OF ROOF SHOWING DANGER POINTS.

Even Sir Christopher Wren, who surveyed the roof in connection with some of the earliest repairs, was deceived by this resemblance, and it must be stated in defence of the great surveyor that where the oak surfaces do not present their characteristic "silver grain" it is remarkably difficult to tell them from chestnut without the aid of a microscope. Where the natural appearance of the wood is disguised by decay and dust, and is seen in the gloom under conditions highly unfavourable for observation, the difficulty is very greatly increased and large whole timbers do not exhibit "silver grain" in any great degree.

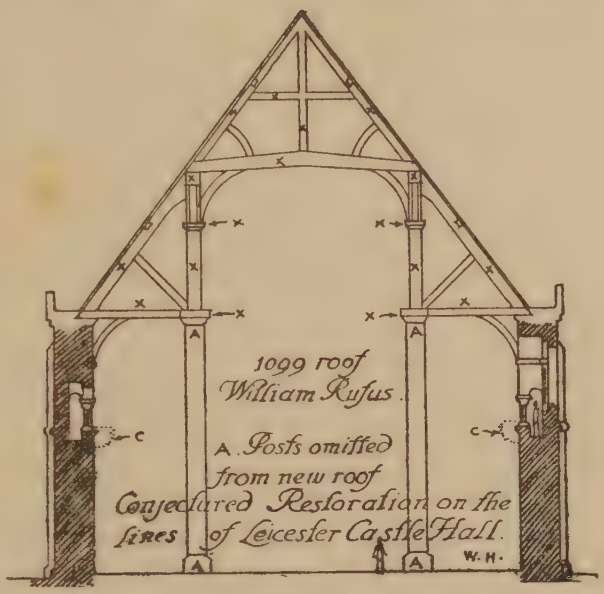


FIG. 140.

The nature of the construction has proved even more baffling to inquiring minds than the substance of the beams. How this first arched hammer-beam roof truss came to be designed has always been a matter of conjecture, and many contradictory theories have been advanced to account for its constructional system. Repairs to the structure in 1835 under the direction of Sir Robert Smirke afforded his brother Sidney the opportunity of examining the construction, with the result that he concluded by pronouncing the design to be of simple collar-beam type with an arch and various enrichments in the way of unnecessary beams, posts and tracery added for ornament. A more reasonable explanation of the Gothic masterpiece was made by Thomas Morris, who recognised

FIG. 141.

that the arch was performing arch-like functions. He pointed out the possible derivation of the great arch rib from the use of actual arches of stone that had been employed for the support of purlins in former examples of Gothic roofs, and explained the use of a hammer beam and hammer post as devices calculated to apply loads to the arch at points chosen by the designer for the purpose of restraining its dangerous lateral thrusts.

While this explanation does not do complete justice to the supporting bracket functions of the hammer beams and posts, or entirely account for their use (since tracery puncheons of adequate strength could have been used to place the weights upon the arch), Morris's theory comes far nearer the truth than many modern accounts, which describe the arch rib as acting in tension and tying the roof together in the absence of a complete horizontal tie-bar. Perhaps the most inaccurate description of all is that in which the hammer-beam truss is likened to a tie-beam truss whose tie-beam has had its central part cut away, for " the strength of the chain is equal to that of its weakest link." Serious attempts to arrive at a more reasoned statement of the structural condition were made when the roof was examined prior to its recent repair by H.M. Office of Works. Stress diagrams were set out to show how the timbers were receiving and transmitting loads, but the fundamental condition of statical calculation by graphic methods is not obeyed in the old Gothic roof.

Although several of the spaces between the timbers are approximately triangular in form, the whole truss is not therefore necessarily a " triangulated structure," and many of the joints are quite incapable of transmitting tensile stresses of any great magnitude. As the repairs proceeded and opportunities for detailed examination presented themselves, it became apparent that any hypothesis which ascribed tensional functions to the joints would have to be abandoned.

By far the greater number of joints in the timbers are made by means of stub-tenons, or even by loose keys and oak pins driven into bore holes, and, supposing the tenons to be new and the pins properly inserted, it is quite impossible that such joints should have ever been supposed by the original builders to have been capable of supporting the weight of the mighty balks they connected. And if they proved insufficient to support the dead-weight of the timber, how could they meet the tensile stresses in the frame considered in the light of a modern triangulated truss of steel ?

Actually several of the stub-tenons had been sheared off in the movements produced in the roof by its own shrinkage and distortion, and by the wind pressures to which it had been subjected during five hundred years. What is even more significant of the designer's frame of mind is that several of the oak pins or trenails were found to have been made of green twigs, and to have been inserted in the most careless and perfunctory manner, although the fitting of the bearing joints was almost mathematically precise.

The designer's intentions in regard to the structural aspects of his great work seemed as incomprehensible as ever; and since calculation and graphical solution only produced conclusions which were absurd in the light of the facts, I therefore set about the construction of experimental models which might show whether the roof truss was not acting as a sort of composite arch weighted and stiffened by a skeletonised wall whose corbel action would contribute to the support of the whole at the same time that it assisted in controlling and directing the arch thrusts.

The first thing to be proved was that a collection of balks could be erected into approximately the shape of the roof and could maintain themselves by balance action. The first models constructed consisted of square-ended blocks piled up without jointing material of any kind. As these models necessarily failed in minute points of resemblance to the actual roof, I afterwards designed others in which the shapes of the timbers were more faithfully represented, but instead of tenon joints they were provided with small notches in which their ends could rest loosely without any possibility of tensile connection.

The models demonstrated in the most surprisingly dramatic way the compressive and balanced action of the timbers in the roof, and by their use it is possible to prove that every timber in the original design contributes towards both the strength and the correct balance of the structure (*see* Figs. 139 to 149).

The proof consists in alternately removing one member or another and finding by this process of substitution the improvement which takes place when all are assembled. Unlike the theoretical calculations which had produced results diametrically opposed to the behaviour of the roof, this practical investigation agrees in all main essentials with the action that goes on in the great Hall itself. The nature and direction of the lines of thrust can be appreciated by handling the model where they can actually be felt under the different loading conditions. Nor is the interest of these experiments confined to the purely academic.

It is sometimes vitally important to know how an old building is behaving, in order that it may be repaired in an intelligent manner. This has not always been the case at Westminster Hall, and on one occasion at least repairs put in hand without full investigation came perilously near to causing the building's destruction. During the construction of the Houses of Parliament, some of Richard II's buttresses were removed from the eastern flank of the hall. Sir Charles Barry prepared a design by which the compressional support of these buttresses might be replaced by inclined tie-bars, reaching up from the wall head to points high up in the roof. To apply these mild steel tie-bars to the roof, holes were drilled in the old timbers, the seatings of the hammer beams on the wall tops were cut short, trimmed up, and provided with cast-iron shoes, and the tie-bars themselves were made with screw couplings to adjust their length and apply pressure to the feet of the principal rafters as soon as the couplings should be revolved.

The design was carried into execution. The tie-bars were threaded through the bore holes and connected with nuts and washers to the cast-iron shoes, but it is doubtful whether the couplings were ever screwed home in the manner for which they had been designed. The tie-bars were found in a slack condition during the progress of the recent repairs, and it seems probable that Sir Charles Barry discovered at the last moment that the tendency of the timber to fail took place in the direction of the centre of the Hall, and that the outward thrust takes place at a point farther down the wall between its top and the level of the corbels which support the wall posts of the roof.

At the level of the wall top the roof was already showing signs of failure through this inward swing of the old timbers, and any undue force exerted in the same direction, whether applied by wind pressure or by screwing the couplings of Barry's tie-rods, might easily have precipitated a disaster. Prior to the recent repairs, the whole weight of each truss was supported upon stone corbels projecting from the walls at points approximately half-way up their height. The corbels are made of Caen stone, and are not strong enough to carry a great load in cross stress.

Richard's builders had adjusted the application of the pressures by means of a spur of oak at the foot of each wall post, so that the weight and thrust were carried by the corbel just where it entered the wall. As the spurs decayed, and as the timbers rocked in towards the centre of the Hall, these pressures came more and more towards the projecting end of the corbel and taxed its cantilever action more severely. One corbel actually fractured between the time when the building was examined and the time when that particular truss—the fifth from the north end of the Hall—could be shored up before repair.

The massive corbel was broken completely through, but the fragment was prevented from falling by the oblique pressures of the oak arch. It was held precariously, squeezed against the wall surface, where the adjoining stones were split by the accidentally applied force.

The history of the building throws some light upon the devices used in the timber framing of the roof, and helps greatly to explain their meaning and their significance to the great masters of Gothic construction who designed and erected it.

It has been mentioned above that William Rufus's Norman Hall was divided by posts or piers into a nave and two parallel aisles, and when Richard II required a new roof in a single span some method had to be found of dispensing with the intermediate props. Nearly three centuries had passed since Rufus's time, and during this period the whole of the civilised world had been experimenting in the use of arches and the devices to be employed in their abutment. The control of pressures in an arch ring by shaping it in a true catenary curve had not been established in the west, although Arab practice shows signs of having come near to this important discovery, at any rate as a commonly

accepted working tradition, even though the theory may never have been enunciated.

East and west alike united in recognising the value of certain expedients in the modification of arch pressures, and builders understood in the most intimate manner all the tricks of masoncraft by which arches of traditional shape could be safely managed and their thrusts controlled. Whether in Cairo or Westminster, a builder of 1394 would turn naturally to thoughts of arches when required to roof a great space, just as the Normans had thought in terms of posts and beams, and as a modern engineer would think in terms of triangulated framed roof trusses.

Although built of oak and not of stone, it is easier to understand the Gothic design of Westminster Hall roof when it is compared with arched and vaulted buildings rather than with modern works of carpentry. Carpenters and masons alike shared a constructional theory which dealt in equipoise and the adjustment of thrusts by means of balance weights, and Richard II's master carpenter, when required to re-roof the King's Hall, could look upon roof building as an affair of compression and balance.

The age of Richard II was an age of magnificence, and under this luxurious tyrant the constructional arts and sciences had reached a point perhaps as high as can be equalled in any other epoch of mediæval times. Constructional science had become standardised, and was conscious of its own powers. Large buildings were being erected throughout Europe and the Near East, and Richard was but following the fashion of his own day in desiring grandiose achievements in architecture.

The three hundred years that had passed since the Norman walls were built had seen the rise of a new theory and practice of highly articulate architecture.

Where the Normans had used large masses of plain walling, the new style would resort to piers, arches and flying buttresses. Knowledge of a much more exact character was permitting the builder to replace brute mass of material by adroitly shaped and skeletonised constructions. It is not to be supposed, however, that Richard's carpenter deliberately set himself to make the first and greatest roof truss of arched hammer-beam type. He may, no doubt, have wished to surprise and delight his fellow craftsmen and all intelligent critics with a work that should prove an advance upon established procedure, and which should epitomise the principles of arch building and skeletonised articulate structure, but there can be little doubt that his invention, like so many other inventions, was in reality largely a question of wise adaptation of existing powers and opportunities.

The Norman roof of the Hall at Leicester Castle, and the roofs of several old barns up and down the country, may be taken as representing fairly, though on a smaller scale, the kind of roof which existed in the King's Hall at Westminster before Richard's renovations, and though

he must have realised that the old Norman structure was hopelessly out of date, the King's carpenter could hardly help being impressed by a mighty work that had stood the test of 300 years.

The contrast of the simple post and beam style of Norman construction with his own more refined and difficult art of arch-thrust management would give him occasion for self-congratulation, but the influence of the old-established precedent would be far greater than the carpenter would himself realise. It would be natural for him to approach his great task of building a roof over the unprecedented span of 70′ in a frame of mind in which confidence in his own science was mingled with well-founded anxiety for the success of the work. He would weigh all suggestions from whatsoever quarter in the endeavour to bring the task to a successful conclusion. Standing beneath the distorted timbers of the old Norman roof he was about to demolish and replace, he would ask himself how and in what respects he could improve upon the old work, and, except where the necessity for alteration occurred in connection with the removal of the in-

FIG. 142

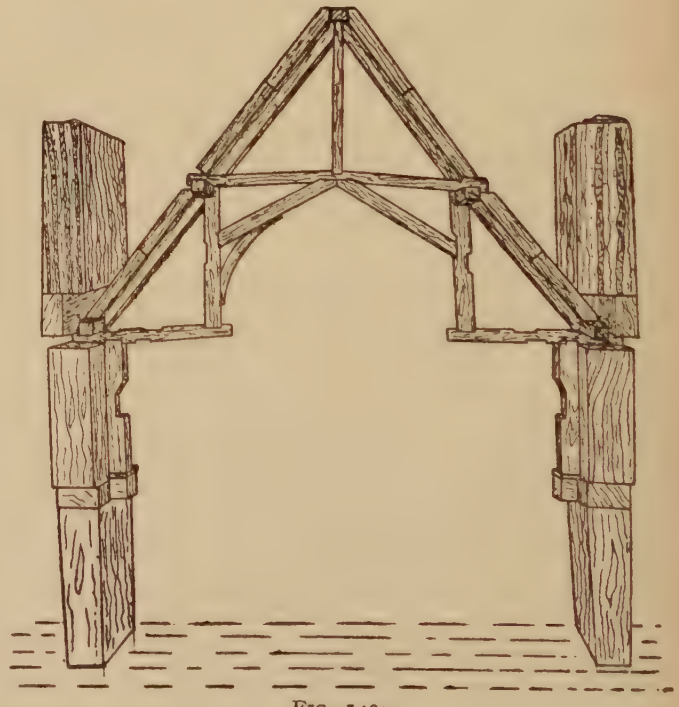


FIG. 143.

FIG. 144.

FIG. 145.

truding posts, he would be content to follow fairly closely the disposition of timbers that had proved capable of enduring since Norman times.

In the roof of Westminster Hall, homogeneous as it is, both as a work of art and as a great constructional feat, two different influences are found to have been blended. It is not simply the arched design, the product of the new arch building theory, but a composite work in which elements from the old post and beam tradition are preserved in amalgamation with the science of arch management. The key to this view of the situation I found when searching for evidence of the probable shape and constructional nature of the Norman roof.

Looking at an old print of Leicester Castle Hall, the idea presented itself that Richard's roof of Westminster Hall might have been designed by the simple process of replacing the large supporting posts by arches spanning from side to side of the Hall, and further examination at Westminster convinced me that such was veritably the case.

The replacement of a pier by an arch I had seen in Salonica, where a small Byzantine church, converted to the uses of a mosque, had

been enlarged as to floor space by the removal of its Eastern pair of piers, squinch arches having been thrown across the corners of the building to take the weight of the superstructure. Richard's carpenter could not solve his problem by merely inserting an arch and hacking away a post, for the whole of his roof was to be new, with every detail and ornament fashioned in Perpendicular and not in Norman fashion, but the hint for some such adaptation of old and new constructional method must have been imparted by the old Norman roof.

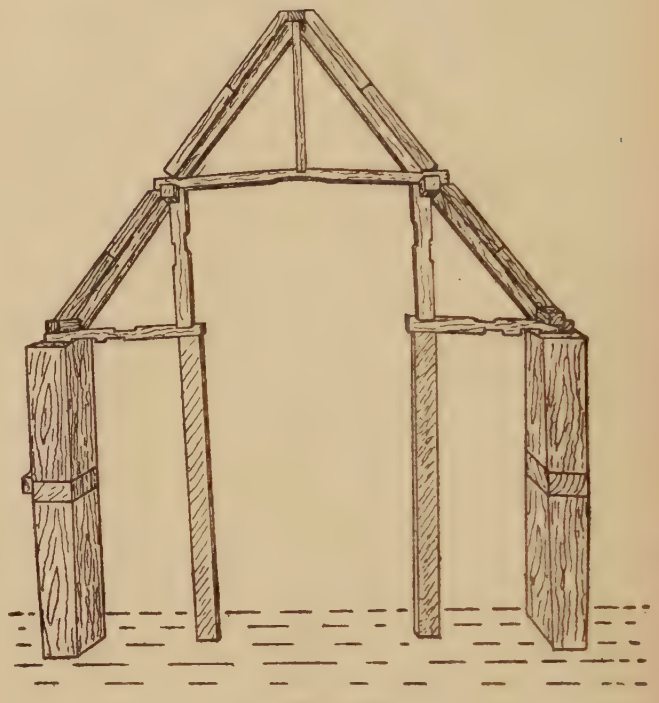


FIG. 146.

And herein lies the wonderful fact of the adaptation. The King's carpenter did not make his new arch the strongest and heaviest timber of the roof. He does not seem to have looked upon it as far and away the most important structural support, although it was his own contribution and the contribution of the science of his own time to the building of a masterpiece.

From the floor of Westminster Hall the hammer beams, with their carved angels and the hammer-posts standing upon the angels' backs, are seen to be

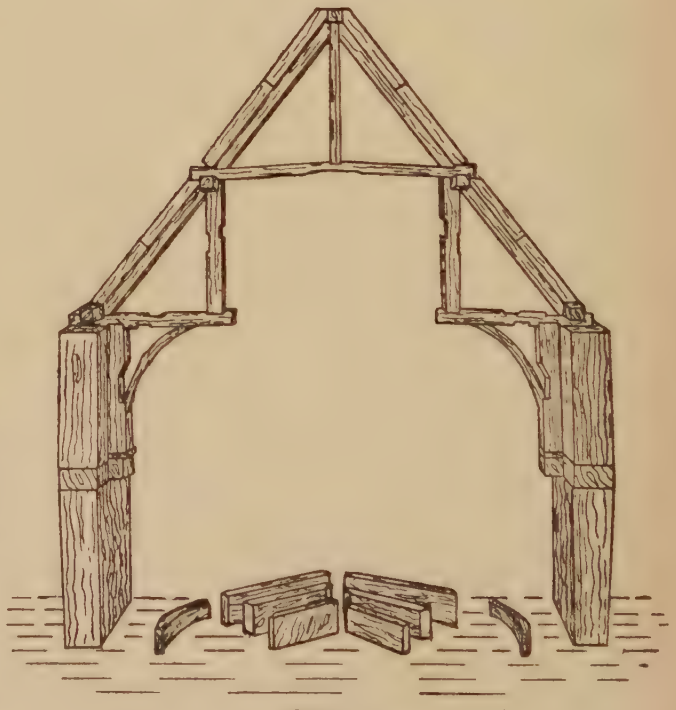


FIG. 147

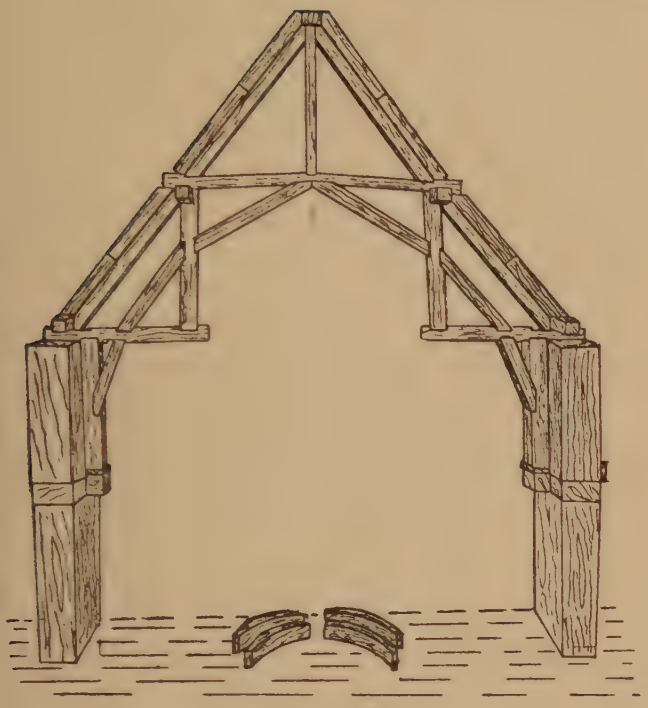


FIG. 148.

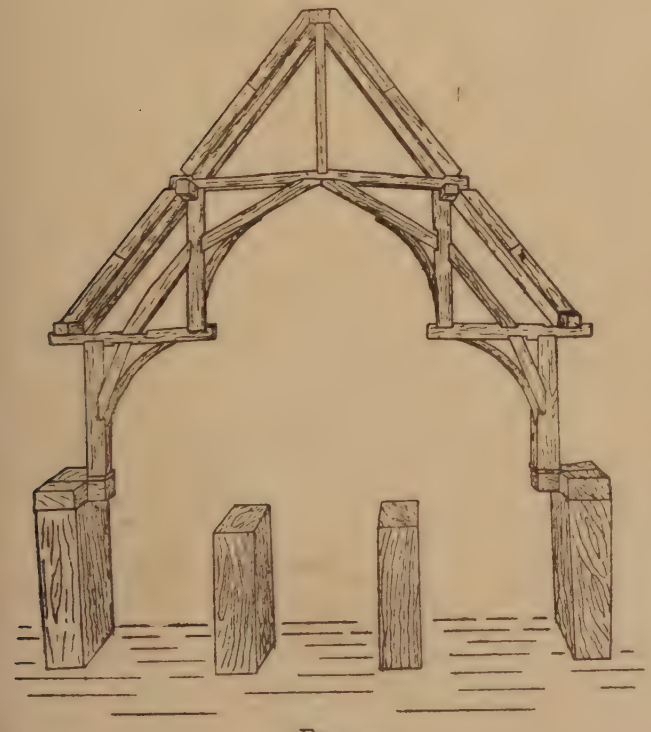


FIG. 149.

enormous timbers, which share with the arch the prominence of primary supports. The influence of precedent can only partly account for the retention of these relics of the post-and-beam tradition, though things exist to show that precedent played its part in the affair.

The something more than precedent that was needed to make the intelligent carpenter preserve the semblance of the old post-and-beam arrangement was provided by the fact that the posts and beams could be adapted to his own "modern" theory of arch management and his theories of equilibration.

Before the great new roof of Westminster Hall came to be designed many structural devices had been invented in connection with the making of roofs. The use of arches of stone weighted by gable walls built upon their backs has already been mentioned, such arches were frequently built from out-corbelled springings, and the value of the corbel, both in reducing the effective span of the arch and in applying its thrust safely and advantageously to the enclosing walls of the building, was thoroughly well understood.

While the thrust of the arch tended to push

the walls over towards the outside of the building, the weight of the corbel and its load tended to overturn them in the opposite direction, and, by playing one tendency off against the other, the adroit constructor of the mediæval period was able to achieve stability without undue expense of material. To keep the corbel or bracket from falling out of the wall, it was necessary to place above it a certain amount of weight, and this might take the form either of a mass of plain walling or of a pinnacle.

The shaping and poising of such masses of top-weight formed one of the most important branches of the mediæval building tradition.

And what the masons effected in balanced stone work, the carpenters achieved by adjusting their rafter pressures and combining the lateral pressures of the rafter feet with the weight of vertical ashlar timbers. This contrivance was intended to bring the weight and thrust of the roof into as nearly a vertical direction as possible, and to apply it upon the inner edge of the wall so that the whole thickness and strength of the wall top would be called into play in resisting the outward overturning action. To give greater power to the ashlar timbers, they were sometimes arranged to stand quite free of the wall top on a projecting cornice inside the building, or upon the overhanging ends of short base plates laid across the wall and overhanging its inner face.

At Westminster Hall the feet of the common rafters are still provided with ashlars inserted in the mortises made for original ashlar timbers 500 years ago. The common rafters for this mighty slope could not be made in single lengths of timber, and are arranged in two stages, the upper range beginning above the level of the framed purlin. These upper rafters retain many of the original ashlars which stand vertically in mortises in the upper side of a large projecting cornice of oak, which enlarges and decorates the purlin. The lower range of rafters has lost its old vertical ashlars, together with the projecting upper member of the cornice upon which they stood, and for which the old housings were discovered in 1915 in the butt ends of the hammer beams. This ashlar timber at the rafter foot was the carpenter's equivalent of the pinnacle used by the masons, and contributed to the stability of the whole roof by its own weight, as well as by its position and by any rigidity it might impart by the accidental triangulation formed by the base plate, ashlar and rafter foot.

In principle carpenters and masons were working upon similar structural lines, the mason's corbel and the carpenter's base plate are both members subjected to cross-stress, and both of them serve to collect and combine a vertical weight with an oblique thrust and apply the resultant force at the safest possible point. Just as a mason of Richard's day could think most naturally in terms of arches and vaults, the carpenter's head would be filled with this see-saw business of ashlars and base plates, and it must have been in this frame of mind that the designer of the new roof approached his task.

The scale of the great Hall forbade the carpenter to trust to an arrangement of common rafters, ashlars and collars, as he might have done over a small compartment. All the resources of the arch-building tradition had to be marshalled to meet the great emergency, and the proposal to eliminate the intermediate posts would call up not only the possibility of replacing them with an arch astride the whole Hall, but would set the designer racking his brains to think of any possible means of stiffening the arch and aiding its supporting action. Looking at the old Norman roof and imagining its most massive posts removed, the designer, under the stimulus of the mighty structural adventure upon which he was about to embark, would search among the remaining portions of the roof for any hint that would aid him in such a hazardous enterprise.

He had to remove the great posts: must he, therefore, depart entirely from the old design? The arrangement of timbers, and even the fashioning of the joints of Westminster Hall roof, show that its designer was content to take a hint from the old post-and-beam construction he was about to destroy.

The size and height of the Norman roof must have necessitated a composite arrangement in the great posts. From floor to wall head was no less than 44′, a dimension which would tax the largest of oaks, and it may reasonably be supposed that the lower stage of the intermediate supports only reached to wall-head level, where they would be crowned by ornamental cushion capitals, which would be burdened with one end of a stout beam reaching from post to wall.

Upon the end of this beam, and in upward continuation of the main post, another post must have stood, and upon its top rested a purlin, and on the purlin the collar beam crossing the central span of the Hall. In the hammer beam and hammer post of Richard's roof the arrangement of these old beams and posts is perpetuated, though their mechanical functions are intensely different in the old roof and the new.

In the Norman roof these upper continuations of the main posts had exactly the same function as the lower parts, and were simply what they seemed to be, compressional supports carrying the purlins and collar beams and the upper part of the roof. In the new design they possess this function, and also others of a highly curious order, for they are also balance weights, purposely intended to weigh down the inner ends of the hammer beams and provide a vertical component which acts in conjunction with the outward thrust of the principal rafter and applies it at the top of the lowest segment of the great arch rib.

The upper part of the old Norman post had suggested to the designer the possibility of incorporating the ashlar timber on an enormous scale in the design of his new roof! My model of collapsible blocks can be adapted to show either the new roof or the old one, and it is surprising to see how many of the main beams of the new roof are but counterparts of timbers that had supported the old one. (*See* Figs. 139 to 149.)

Examined in detail, Richard's roof is found to be sharply divided into two groups of timbers, the straight timbers being simple, solid balks provided with comparatively small stub-tenon joints, while the curved timbers are made with much more elaborate joints. The great arched-ribs are composite constructions of three parallel timbers fastened together with oak trenails. Outside the pair of outer timbers are wooden label mouldings affixed with iron nails, and these doubtless contribute somewhat to the strength of the whole.

The joints, where the arched rib passes the hammer post and hammer beam, exhibit a great step in advance from the stub-tenons used throughout the rest of the work, and have been halved in a way that permits the various timbers to obtain a certain amount of seating one upon the other.

Had the same quality of design extended to the joints at the apex and the springing of the arched rib, the supposition that it might act as a tension member would not be altogether absurd, though this is not the case, and the only provision for tensile connection at these important points is made by comparatively small oak tenons, keys and pins.

Although this Gothic system of compression and balance is no longer the principle favoured by modern engineers, it was none the less highly efficient when exploited by masters familiar with its usages, and the decay of Westminster Hall was not due to any failure of the design as a scientific work.

Signs of decay were indeed so little noticeable that the proposal to spend large sums of money first on examining and then on repairing the roof was met by protests of the most forcible kind. Architects were found who declared that the roof, though old, was in a substantial state of repair, and the Office of Works plan for putting in hand a far-reaching scheme of steel reinforcement in the form of auxiliary trusses hidden among the old timbers was considered as the work of alarmists.

No one could believe that the solid-looking timbers had been reduced in internal section until they were no longer of sufficient strength to carry the extraordinary load of the great roof. Unfamiliarity with the difficulties which attend the examination of an ancient structure was at the root of some of these objections and misunderstandings.

The Historic Buildings Branch of H.M. Office of Works possessed authentic information concerning the nature of the internal decay, but no one else was in a position to possess an opinion that was founded on anything better than outward appearances, and these were, in this case, highly deceptive. That they were so was due to the peculiar habits of a small insect known as the death watch beetle, whose larvæ (wood worm) spend a considerable period burrowing in the interior of a timber before coming to maturity, when they advertise the damage they have wrought only by a single round hole on the surface of the wood.

At Westminster Hall even these flight holes were not conspicuous. By far the majority of them were formed in the dark upper surfaces of timbers remote from inspection, and the most dangerously and exten-

sively excavated portions of the roof were important bearing joints which gave to the insect two opportunities it requires for its destructive work.

To start the young grubs in life, the eggs are laid in some small crevice in the timber, for the soft "wood worm" requires a solid support for its back in order to obtain the requisite driving power to force its jaws into the tough oak. These ideal starting places the mother beetle finds in the natural fissures of the surface, occasioned by shrinkage, and in the joints between one timber and another.

Darkness is another condition which is sought by the beetle, so that the gloomy corners where several huge beams meet naturally became the scenes of the greatest infestation and the greatest damage.

The life history of the beetle is still incompletely investigated, and, before the recent repairs to the roof, comparatively little reliable information was available, so that even the careful preliminary investigation failed to reveal the full extent of the excavation in the heart of the timbers, though enough was discovered to indicate that a most dangerous state of things existed. It was not until the repairs were actually put in hand that the size of the cavities in the beams could be realised. Hammer beams and main collars were found of which the interior had been eaten away until a shell from an inch to three inches in thickness alone remained.

The complaint that steel reinforcement would be foreign to the principle of the old wooden roof proved to be of no practical weight, for nothing less than an adequate and properly calculated steel truss could have been relied upon to carry the roof. The alternative proposal to mend the roof by splicing on new pieces of oak with the help of steel bolts and fish-plates would have meant using more steel than was required in the new auxiliary trusses, for it would have been used at a disadvantage and in a way that would not have permitted any rational calculation of strength to be made. As things were arranged, it was not only possible to calculate the amount of steel that would be required, but to control the application of the loads upon the old walls, where the new steel trusses are fixed upon steel cantilever seatings.

As the repair to each of the oak principals was completed by the assembling of the last of the new steel plates, bars and bolts, the seating of the whole upon its bearings was put in hand. A careful calculation was made with the object of ascertaining the effect of the load of common rafter and roof covering in causing outward spread of the scissor leg of the truss, and that no unnecessary risk should be taken, a practical experiment was made to determine the amount of spread in response to forces of known magnitude. The tension members of the new steel work were adjusted by the revolution of great steel unions, and the legs of the truss drawn somewhat together by this means, the feet being provided, for the time being, with a movable seating upon steel rollers.

The feet of the truss were next forced apart to a distance calculated

to represent the final deflection under the full load, with such additions or subtractions as were necessary to correct known tendencies of the old and overhanging walls below to move in one direction or the other. The fallacy of the assumption that the old wooden truss possessed members acting in tension is well illustrated by contrasting its $\frac{3}{4}''$ diameter pegs of oak with the great 5″ diameter pivot pins of steel, which were found necessary to connect the tension members of the new steel trusses.

One curious aspect of the roof of Westminster Hall concerns the repairs that had been applied to the building from time to time. To mend it in 1663 two hammer beams and two collar beams were patched and three new purlins inserted. At the same time the common rafters were firred up and the lead made good. The firring up of the common rafters is significant in that all future repairs were to partake of the same character. Firrings are intended to make out the shrunken and distorted timbers to an appearance of regularity and strength; the structural benefit to the roof obtained by their use is practically nil, and as time went on successive repairs became more and more trivial, useless and even dangerous. It has been shown how nearly Sir Charles Barry's tie-rods came to producing a final distortion that might have resulted in cracking the corbels and allowing the roof to fall bodily to the ground.

Other repairs were dangerous in another way, in that, like the firrings of 1663, they were directed at preserving appearances and disguising the extent of the decay. Such repairs place a terrible handicap upon succeeding investigators and custodians of a large building. The cost of scaffolding alone that would be needed for the examination of any truss in Westminster Hall is considerable, and although periodical examinations should be made of all ancient structures that have endured for periods which render their continued existence somewhat problematical, these inspections tend to become perfunctory.

At Westminster Hall, prior to the recent repairs, this important duty devolved upon the scaffolders, who had also to brush a certain amount of dust from off the old timbers. These old sailors made use of a portable tripod ladder, which was provided with an extending arm, whose motion, as one climbed it, was distinctly reminiscent of that of a mast in a storm. A heavy man on the summit of the extension ladder could just communicate a movement to the tripod base that seemed to imperil the stability of the whole precarious arrangement. The bearings these details have upon the examination of the roof is just this: that compared with the shaky ladder the great beams seemed as safe and as steady as possible, and the only report that the sailor could bring down would be one to the effect that though the roof was not so young as it used to be, its state was "queer" rather than dangerous! Needless to say, their use of the word dangerous referred to personal feelings, and was not founded upon the experience that a surveyor would bring to the examination of a dangerous structure.

Others besides scaffolders and sailors were deceived by the apparent soundness of the roof, and the part played by patchings and repairs which aimed at keeping things tidy must have contributed to the deception. Worm-eaten hollows in the old timbers had been covered with wainscot panels of perhaps half-an-inch thickness to hide the decay, or had been stuffed with little billets and wedges which might or might not help to resist the immense pressures in the old roof.

In general, the earlier repairs of 1663 were far better and more conscientiously applied than those of later date. Sir Christopher Wren and his contemporaries may not have understood the whole Gothic contrivance, but they were at least competent to stitch in a bolt where it would hold things together, instead of where it would assist in pulling them apart.

Another thing that confuses the estimate, even of a conscientious surveyor, is the difficulty he experiences in calculating the amount of movement that is taking place in the building. Accurate records are seldom available to show the exact size and shape of the building when erected, and even the discovery of undeniable bends and bulges does not necessarily prove that the building is on the point of tumbling down.

The original builders of the Norman period certainly built in a way which would appear distinctly irregular at the present time. Fragments of their work discovered in the walls of the Hall during the recent repairs included the remains of a most beautiful arcaded wall passage which had permitted of access to the Norman windows. Now this arcade shows signs of extraordinary regularity on either side of the Hall, but, strangely enough, the arches on the two sides of the Hall are not opposite to one another, the departure from regularity exceeding six feet in some places.

But while errors in setting out are responsible for this particular divergence from the square, the overhang of the walls and their bowing out in the middle of their length may be reasonably ascribed to accidental settlement due to imperfectly buttressed arch and rafter thrust. It was not till after the whole building had been surveyed that the very great movements that had taken place among the timbers could even be suspected. Comparison with the slope of the gable wall indicated that other parts of the roof had sagged away 18″, though the deflection had been disguised and eased off by the firring already mentioned. It was a matter of great interest to me to reconstruct the design of the old roof in accordance with the slope of the gable, and to find among the timbers unmistakable signs that the roof had been set out in this manner.

My investigations showed that the hammer beams had originally been given an upward camber towards the middle of the hall to match the camber of the underside of the great collar beams. I had first suspected that this might be the case when setting out the framing to agree with the slope of the gable wall; afterwards I was enabled to verify

the point by referring to the tracery from the triangular space between the hammer beam, hammer post and great arch rib.

The tracery bars or puncheons had been violently forced out of alignment by the downward droop of the hammer beam, but it was possible to measure the extent of this dislocation by referring to the levels of similar points in the ornamental tracery attached to each bar. A double check was possible, for the puncheons were provided with stops to their mouldings at their feet as well as cusps at their heads, so that the buoyant setting out of the design could be established without a doubt.

CHAPTER V

STAIRCASE BUILDING

Definition of a Stair—Design—Theory of Stairs—Types of Staircases: (1) Straight Flight, (2) Landing and Newel or Dog-Legged Stair, (3) Geometrical or Wreathed, (4) Single and Double Flights Combined—Setting Out a Staircase—Setting Out Winders—Definitions of Parts of Staircases—Construction of Staircases—Jointings Used—Carriages—Bracketing—Hand-railing.

STAIRS require workmanship of the most skilled nature met with in the construction of a building. They are constructed in the joiners' shop and sent to the building to be fitted; considerable care and knowledge are required in their planning; ingenuity in setting them out and very skilful workmanship in their erection render them a very highly skilled operation.

DESIGN

GENERALLY.—The object of stairs is to give access from one floor in a building to another, and they are constructed in wells which are practically passages running vertically instead of horizontally. The main requisites in designing a stair are: (1) That the access should be effected in as direct and inexpensive a manner as possible; (2) that the ascent should be as economical of physical effort as may be when considered in conjunction with economy of horizontal space in floor area; (3) that sufficient head room, or distance measured at right angles to the line of the flight to any projection or ceiling above it, should be secured.

ACCESS DIRECT AND INEXPENSIVE.—These matters being the bugbear of all designers, some slight digression on the subject may not be out of place. The designer of any building, no matter of what class so long only as it has more than one floor, will not have proceeded very far in the lay-out of his plan before he finds himself faced with the amount of floor area which he must leave for his staircase. The disposition of the stairs will also present some difficulty, in that they must be placed so as to give access to as many of the rooms as possible, in as direct a manner as possible, and at the same time, whilst the last requirement would suggest a central position as being the most suitable for them, the matter of lighting must not be lost sight of, as it is perhaps of more importance on a stairway than in any other part of a building.

By the statement that the disposition of the stairs must be such that access to the rooms shall be as economical of space as possible is meant that not only shall the stairs lead from one floor to another as directly

as may be, but also that the distance from the point where they arrive at the floor above to the doors of all the rooms shall be as short as may be desired. The shorter the distance the better the planning. At the same time, stairs must be so planned that they do not start or arrive

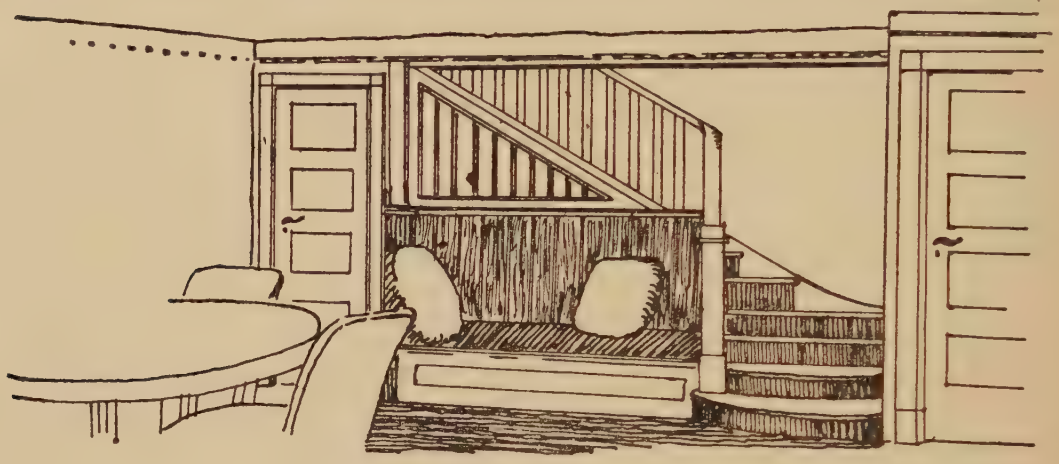


FIG. 150.

in too close juxtaposition to a doorway as to interfere with or be a danger to anyone using the stairs. Stairs arriving at an upper floor in such a position that will call for long passages to give communication to the rooms on that floor are obviously not economical; at the same time, stairs should be situated wherever possible on an outside wall, so as to enable horizontal outside lighting rather than vertical lighting, from a skylight in the roof above the stair well.

As regards the flight or flights, it will be obvious that the more direct

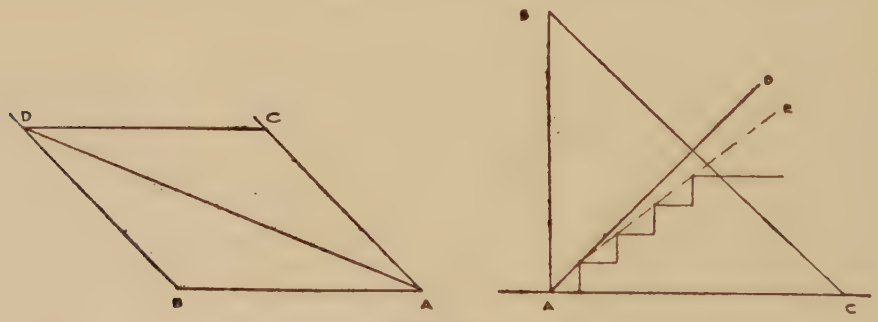


FIG. 151.

these are the more economical of construction they will be; and economy of construction is also achieved by having as few steps as possible to give the ascent. But this last, whilst economical of space and construction, is anything but economical of physical effort in both mounting and descending.

Economy of Effort.—It is an elementary principle of mechanics that if two equal forces applied upon a body and acting in the same plane be represented by two straight lines inclined to each other, their resultant will be equal to the diagonal of the parallelogram formed on their lines.

Thus if the line AB and AC (Fig. 151) represent two forces acting on one point A, and in the same plane, then to obtain the resultant, or the force that would have the same effect as the two forces, the parallelogram ABDC must be completed and the diagonal AD be drawn. This line AD will then represent the resultant of the two forces, and the line on which the body will move with the least resistance as the result of their combined energies.

Applied to a body which it is desired to raise from one floor to another by means of a line along which there will be the least resistance the principle just enunciated gives the following result. The two lines of motion of a body which it is desired to move from one floor to another up a diagonal staircase may be diagrammatically represented by a vertical line operating in opposition to the force of gravity and a horizontal line representing the distance that body is transferred horizontally. In other words, a right angle is formed as in Fig. 151, BAC. When B and C are joined and the line bisected at the point D, AD gives the resultant along which the body will travel with the least resistance in being transferred from A to the height of B.

However, this line of progression would be comfortable only where the two forces AB and AC were equal, whereas the force of AB is necessarily greater than the force AC, because the force of gravity requires greater effort to overcome it than that force which is required to propel the body horizontally. So that to obtain the line along which the body A may be propelled with the least resistance, i.e. with the greatest comfort to the body, a resultant must be taken forming an angle with the horizontal which would be the resultant if the force AC were greater than the force AB. This, in the case of a person progressing up a staircase, is to say that the ascent will be most comfortable when the force necessary to propel the body horizontally is slightly greater than that necessary to raise the body vertically. And, as in the action of walking horizontally the body rests upon a support, in this case the steps, the resultant energy expended will be counteracted by such support, and at the same time the expenditure of energy in raising the body from step to step will be periodic and less felt.

From such reasoning the conclusion may be drawn that the most comfortable staircase will be one that causes a body to rise vertically slightly less than it progresses horizontally. And this, having been investigated mathematically, has been reduced to actual dimensions, the principles governing which are embodied in various rules as explained later.

Economy of Floor Area.—Having due regard to the principles just

explained, it would seem that the staircase which would involve the least expenditure of energy in mounting would be one which ran in a single flight along the line of least resistance. However, whilst this might be so, the length of the flight of continuous steps is inadvisable, for two reasons. The first, that without the provision of some halting place the time during which the effort would be required to be sustained would be in itself tiring ; and also the floor area which such a flight would occupy in a staircase well would rob the floor of that space which might be more suitably occupied by rooms.

Consequently for both of the foregoing reasons a halting space is arranged at some point in the run of the flight, and in some cases it is more convenient to continue the flight in the same direction, when the halting space serves only as a rest, but more often the halting space serves the additional purpose of giving a turning in the direction of the flight and so resulting in a saving of the floor area occupied both at the bottom and the top of the staircase. This halting space, as explained later, is termed a landing.

Head Room.—It will be obvious that in rising from one floor to another by a staircase, a point will be reached whereat the head of a person ascending the stairs would come into contact with the floor above unless this were cut away at a convenient point. This distance is termed head room, and is measured either vertically or horizontally from the line of flight of the stairs to the point where the floor above is cut away or to the underside of a flight above. Where staircases have a halting space or landing as is described in the last paragraph, it would be a reasonable thing to suppose that the most convenient place for this to be arranged, taking into consideration the comfort of the person mounting the stairs, would be at half the height of the staircase. However, in general practice it is found that the landing is arranged at a height so that a convenient head room may be obtained underneath the landing and the floor space used. Consequently the landing is generally situated at at least two-thirds of the height of a flight. Where one flight comes above another, as has been said, the space between the two flights must be calculated to give sufficient head room, and in the case where the landing is arranged on the first flight a similar landing giving sufficient head room will need to be included also in the second and other flights. Cutting away to give head room in the floor of a building for a staircase is termed the formation of the staircase well. And with regard to planning, it will be evident that a compromise must be effected between the amount of space given up to head room, and that which will require to be left for giving access to the rooms on the floor above. For instance, as shown in Fig. 150, access is just permitted by the projection of the floor to a point over the flight of the stairs below, and if the distance be measured from the edge of that floor to the flight of the stairs, it will be found that bare head room has been given. This is an example of economy of planning as applied to stairs.

FIG. 152.—PANELLED STAIRCASE WITH CARVED DETAILS.

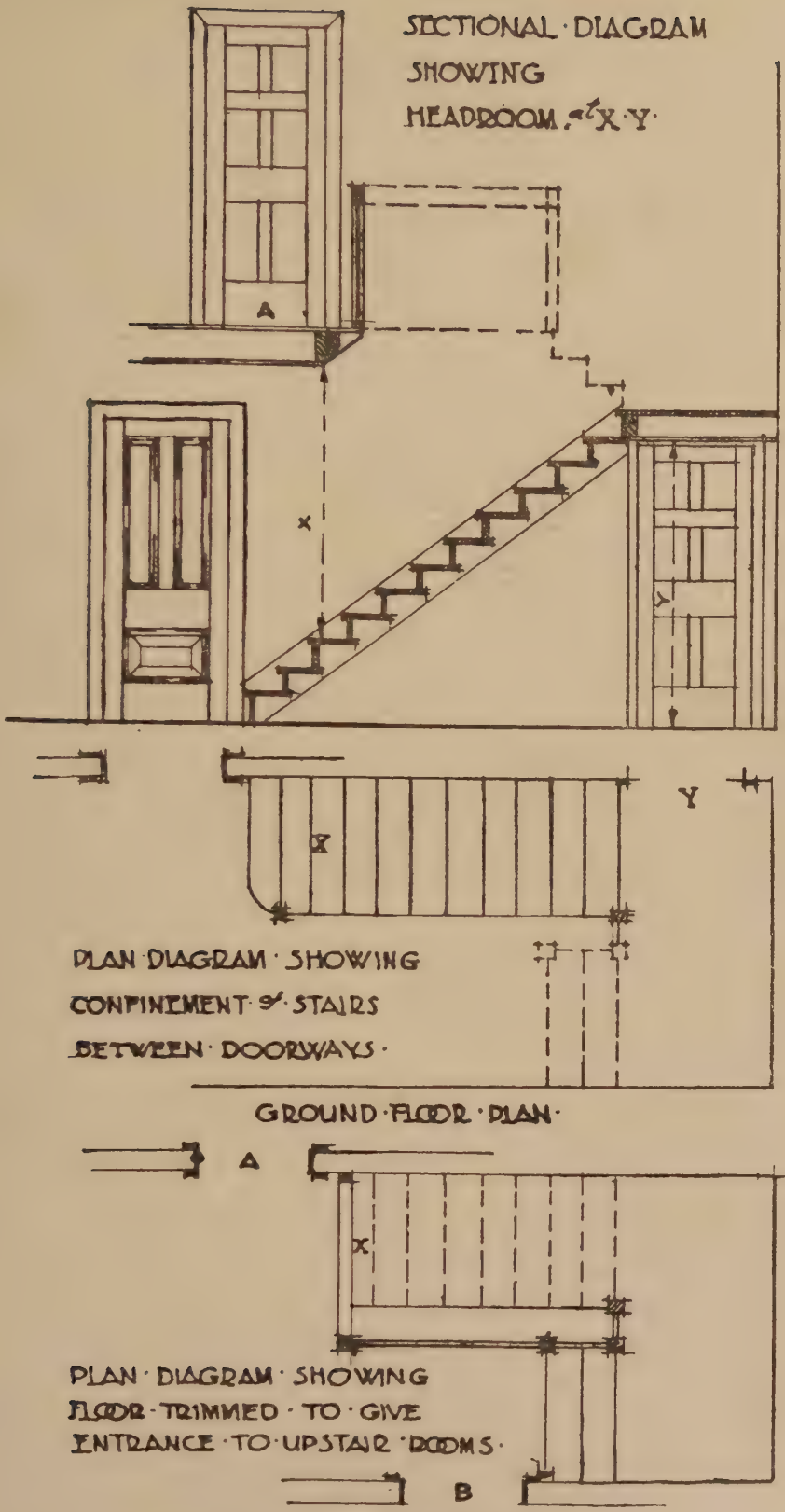

SECTIONAL DIAGRAM
SHOWING
HEADROOM = X Y
A
X
Y
X
Y
PLAN DIAGRAM SHOWING
CONFINEMENT OF STAIRS
BETWEEN DOORWAYS
GROUND FLOOR PLAN
A
X
PLAN DIAGRAM SHOWING
FLOOR TRIMMED TO GIVE
ENTRANCE TO UPSTAIR ROOMS
B
FIRST FLOOR PLAN

FIG. 153.

Theory of Stairs

Proportion of Rise and Tread.—As mentioned in a preceding paragraph, progress is made up a staircase by motions alternately vertical and horizontal. The distances travelled vertically are termed the *rise*, and those travelled horizontally are termed the *treads* of the stairs, and as was also explained, the relationship of one to the other has been investigated mathematically, and the principles governing this are embodied in various rules.

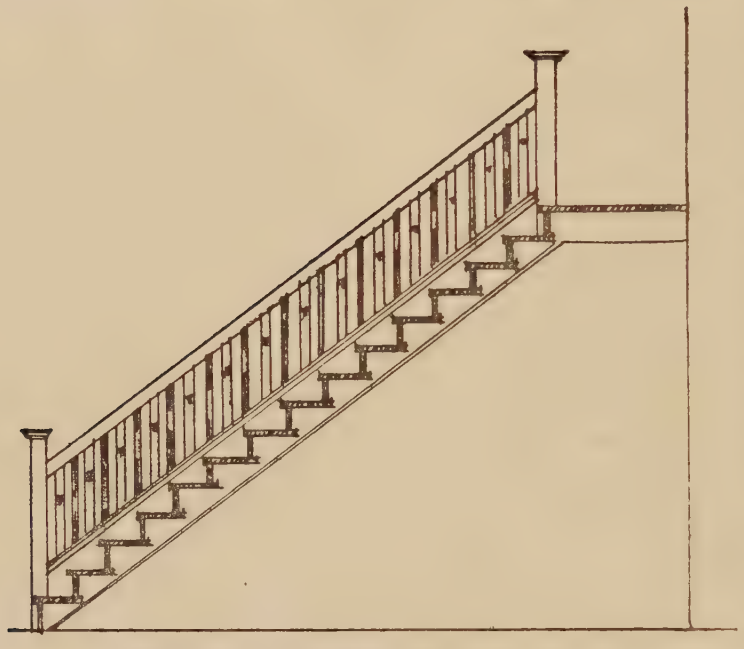


Fig. 154.

Of these the following are the simplest: (1) The sum of the rise and tread should be equal to from 17″ to 17½″; (2) the sum of two rises and a tread should not be less than 24″ and not more than 25″; (3) the product of the rise and tread should not be less than 70″ and not more than 75″.

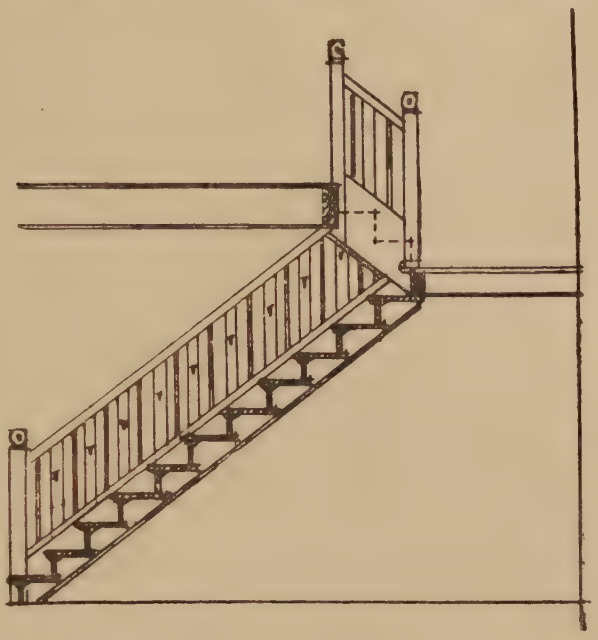
A tread should not be too narrow nor a riser too high, and in a private house a convenient ratio between riser and tread is as 7 is to 9. A tread of 12″ wide with a riser of 6½″, as is often found in large houses, hotels, etc., will be found in practice to give a somewhat tiring staircase.

Fig. 155.

Types of Staircases

The Straight Staircase.—A single flight in one direction is termed a straight stair, and as has been pointed out, it is often found in practice to be too tiring. In some instances, to avoid the necessity

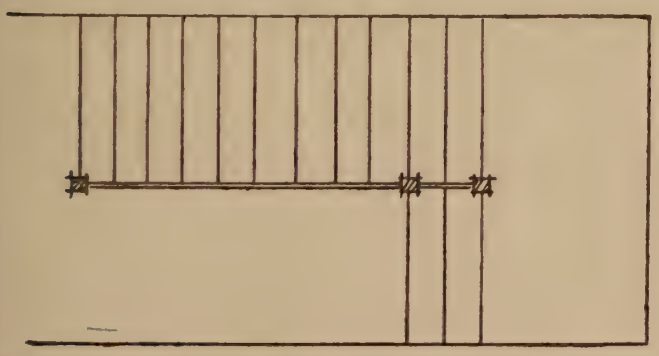
for a straight flight having every step in the same direction, a few of the bottom steps, or the top steps or both, are radiated from the newel post as centre. These steps are termed *winders* and, though of common occurrence and adding to the artistic appearance of a stairway, are to be avoided if possible, as they are not only inconvenient for the passage of furniture and for the straightforward laying of the staircase, but are often quite dangerous, especially for children.



SECTION OF DOG-LEG STAIR.

Fig. 156.

Straight stairs sometimes have a landing in their length which extends across the whole width of the flight and should not be less than 3′ 0″ in depth. However, the method is not to be recommended, as it is uneconomical of space, also it is often the cause of accidents from falling, owing to the unexpectedness of the change of direction coming without a turning or other sufficient warning.



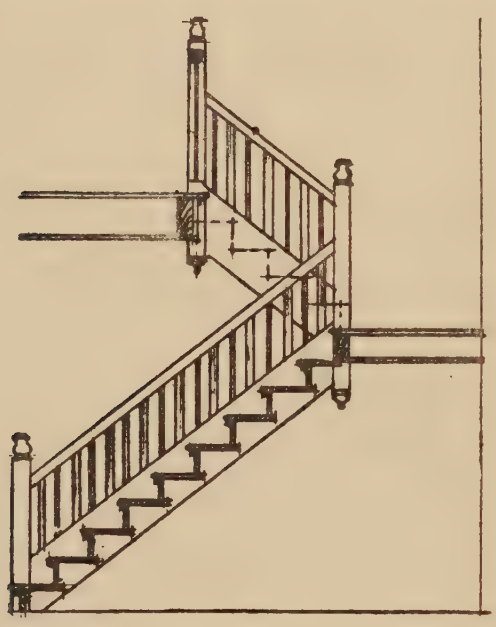
PLAN OF DOG-LEG STAIR.

Fig 157

Landing and Newel or Dog-Legged Stair.—The simplest method of overcoming the chief objections to a straight stair is to construct the stair in two flights having a landing between them on which a turn is made and the direction of ascent reversed.

This form of staircase is termed a dog-legged stair, and the outer edges of the two flights being in the same plane there is consequently no space between them. As has been mentioned, floor space is saved by this method, but from this saving will have to be deducted that space

occupied by the landing, which should not be less than 3′ 0″. Also the width of a well for a single flight will in the case of the dog-legged stair be doubled.

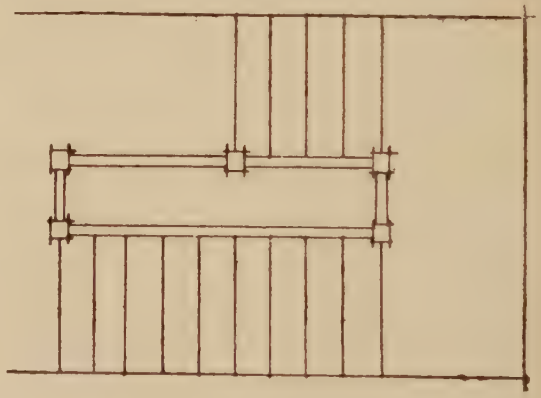


SECTION OF OPEN NEWEL STAIR
FIG. 158.

As is explained later in the construction of stairs, a *newel* post is found necessary to receive the *outer string* or board into which the ends of the steps are housed at the same time as the string and handrail of the upper flight are housed into its upper portions. Whereas in the open newel stairs a space is left between the two flights and one newel post takes the string and handrail of one flight only.

The landing in a dog-legged stair is termed a half-space landing, which is one that extends across the whole width of both flights. However, this landing, for reasons of economy of space, is often occupied by winders. But, as already explained, winders can scarcely be recommended as safe, and nowhere is this more marked than when occurring in a dog-legged stair, where as many as seven steps may come to a point at the single newel, giving as much as 4′ 0″ vertical drop at that point.

The OPEN OR NEWEL STAIR, as distinguished from the dog-legged stair, has a *well hole*, or space between the two flights which necessitates the use of either a very wide newel or two newels, according to the width of the space between the flights. This method also permits of the introduction of one or two steps in the width of the landing and the consequent dividing of the landing into two landings at different levels. Each portion of the landing is then termed a quarter-space landing. It is important to note that the dividing of



PLAN OF OPEN NEWEL STAIR.
FIG. 159.

two quarter-space landings by one step only is to be rigorously avoided, as the practice has been proved as the result of an action at law to be exceedingly dangerous, as the mental effort necessary to prepare the limbs for the requisite action of encountering a change in level is not sufficiently excited by one step only.

This class of staircase is usually found in better-class buildings, and amongst its advantages are that where no side light is possible the open well enables a certain amount of light to have passage from a skylight above to the lower flights.

Its disadvantages are the greater width of staircase hall required, and that its use encourages winders, as already pointed out.

The space between the bottom and top flight may be so enlarged, and the two quarter-space landings divided by a number of steps, so that the staircase becomes practically three flights running along the walls of the staircase hall, or alternatively, as is often seen in large houses or hotels, the landing—a half-space landing—may be extended across the hall until it becomes a gallery. Such galleries are frequently bayed out over cantilever brackets, when they may be used as lounges, giving pleasing vistas of the hall below, or, as in old work, as a musicians' gallery.

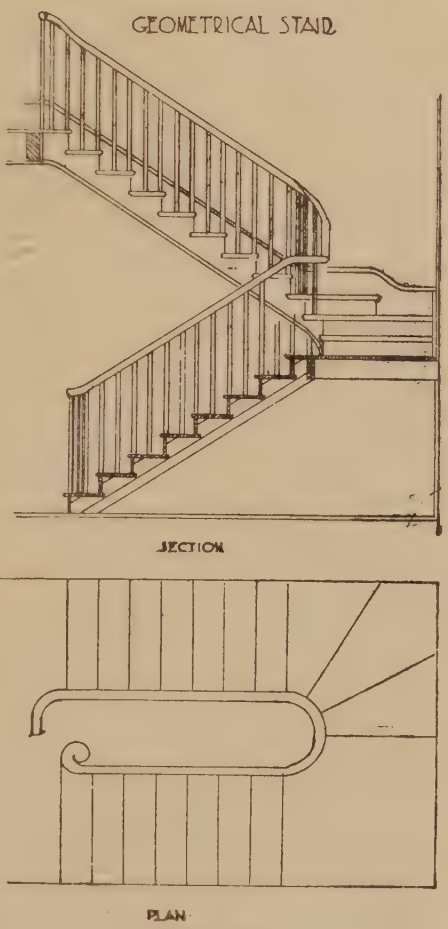


FIG. 160.

GEOMETRICAL STAIR.—This is one in which the setting out of the strings and rails is based upon geometrical principles, and one or both of the strings and handrails run continuously without the introduction of newels from top to bottom of the flights, which are continuous. Though the staircase well itself may be, and generally is, rectangular, the corners of the flights are rounded off, and the inner angles of the well hole are either in circular or elliptical curves.

In a stair of this type the introduction of winders is a matter of necessity; but in order to overcome the danger occasioned by several winders coming together at points vertically one over the other, they are set out to radiate from varying centres—and become known as

dancing steps. This method not only increases the *going* of the steps, but also gives a more artistic and graceful line in the sweep of the string and handrail.

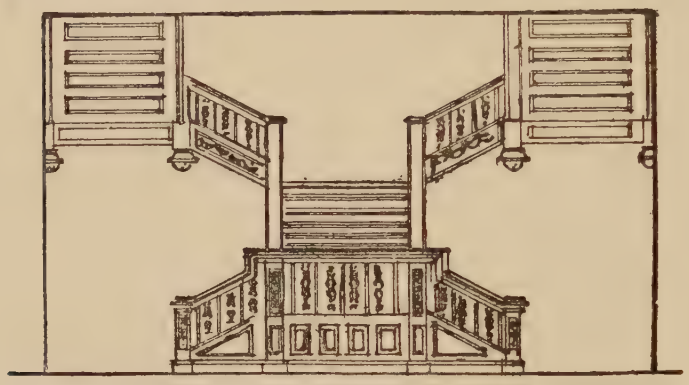


FIG. 161.—SINGLE AND DOUBLE FLIGHTS COMBINED ELEVATION.

SINGLE AND DOUBLE FLIGHTS COMBINED. — In entrance halls to large buildings, such as public libraries, town halls, hotels, etc., a staircase often commences with a single flight, and is continued from a landing both right and left, turning again on quarter-space landings and reaching the floor above on either hand of the point from which it started.

Conversely, staircases are also commenced with two flights combining into one in their upper portions.

CIRCULAR STAIRS are a type of geometrical stair, having a centre newel built up of the inner portions of the treads, but as they are usually built in stone, they do not come within the province of the present work.

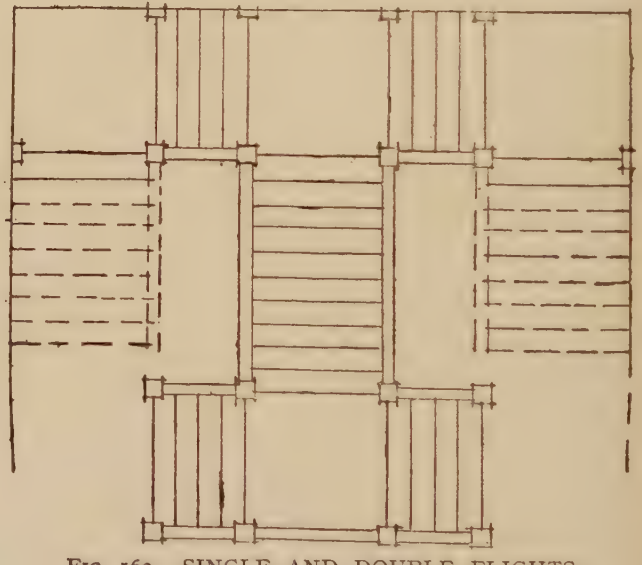


FIG. 162.—SINGLE AND DOUBLE FLIGHTS COMBINED PLAN.

PATENT BALUSTERS AND HANDRAILS. — Mr. G. T. Knight, of Ontario, Canada, has patented an economical and time-saving method of constructing balusters and handrails. In his invention a baluster and railing structure, comprising a main baluster (11), auxiliary balusters (36), upper and lower railings (34, 35), and a false post (33) is built up from a number of separable elements that are readily assembled or taken down. The main baluster (11) comprises vertical boards with mitred edges keyed together and received within a socket (14), similarly constructed from mitred boards

(17) and a frame (15). The top (20) of the baluster receives the screwed end (25) of a hooked rod (22), the hook engaging one of a number of holes (23*a*) in a floor-board to secure the baluster in a vertical position. The wing-nut (26) engaging the rod is covered by a board (30) spaced from the baluster by a frame (29). The railings comprise a core (37) having vertical pockets at intervals to receive the upper and lower ends

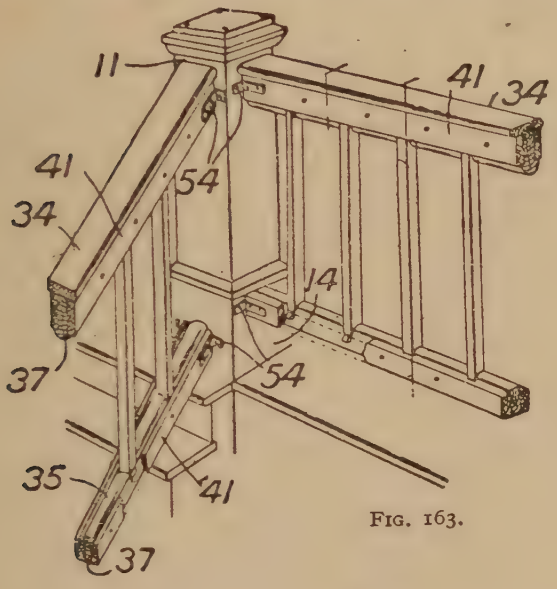


FIG. 163.

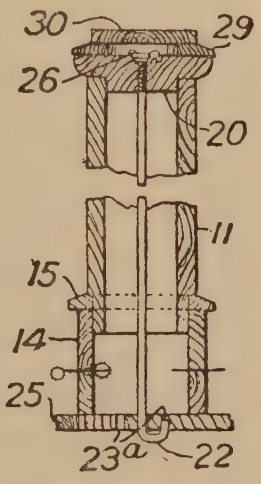


FIG. 163*a*.

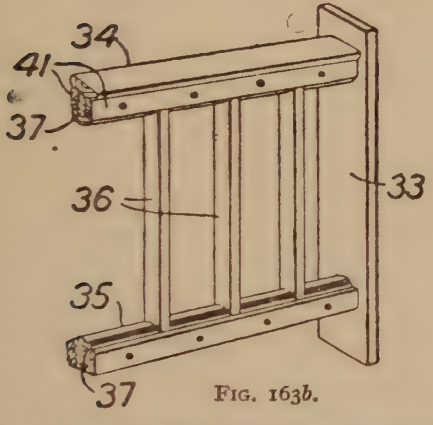


FIG. 163*b*.

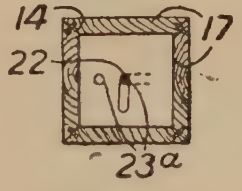


FIG. 163*c*.

of the auxiliary balusters (36), these ends being dovetailed into recessed side members (41) that are secure to the core (37). A flat board (34) is secured to the upper surface of the upper railing. The railings are secured to the main baluster by easily removable brackets (54) and to the false post (33) by screws. In constructing the portion of the railings that rail off the stairs, the ends of the auxiliary balusters and railings are cut at suitable angles.

CHAPTER VI

SETTING OUT A STAIRCASE

On Paper—Laying out a Stair in the Shop—Winders—Risers around Cylindrical Openings—Definition of Parts—Strings—Steps—Tread—Riser—Nosing—Carriages—Soffits—Capping—Landings—Well—Range—Scroll Wreath—Newels—Balusters—Pitching Piece—Trimmer—Fascia—How to Lay Out Easements—Handrailing—Drawing Ellipse and Scroll—Face Mould for Wreath.

To the beginner in design the setting out of a staircase will present one of the main difficulties of his design, and, as the experienced designer will know, it is a matter to which very careful consideration must be given at an early stage in the operations, as so many other matters depend thereon.

On Paper

Having, as mentioned earlier, decided upon the relation of the stairs to the rooms, into which the matter of aspect and lighting will enter, the main requisites will be directness and a saving of passage space. So far as aspect is concerned in a domestic building where it is naturally desired that as many as possible of the living-rooms should face the sun, it will be obvious that the staircase will be relegated to another side of the building ; and, whilst a view is desirable at all times, it will not be of such importance from the stairs as from a living-room or bedroom. But lighting, on the other hand, is a matter of the very first importance, though one so often overlooked. Wherever possible a staircase should have at least one outside wall on all landings and galleries, the largest windows possible in the space should be provided ; also portions of such windows should be hung to open to provide ventilation of a space that will otherwise very soon become stuffy, especially in houses. Top lights in the form of skylights are better than no lights, but are best avoided wherever possible, and are only of use over staircases where there is an appreciable well between the flights.

At the same time as that a staircase should have at least one outside wall, to be most effective, it should be so planned that it lands at a point as near as possible to the doors of the principal rooms on that floor, thereby saving space in passages.

Method.—The position of the staircase having been decided upon, it remains to plot it upon the plan, and the method employed involves the simultaneous consideration of the plan and section. If, for example, a stair having a tread of 9″ and a riser of 7″ be taken, the number of risers

is found by dividing the height of the room plus the thickness of the floor by 7, the quotient being the number of risers. E.g. if the height from floor to ceiling is 8′ 0″ and the thickness of plaster ceiling, floor joists and floor boards, 9″ together, these equal 105″, so that $\frac{105}{7}$ equals 15 risers.

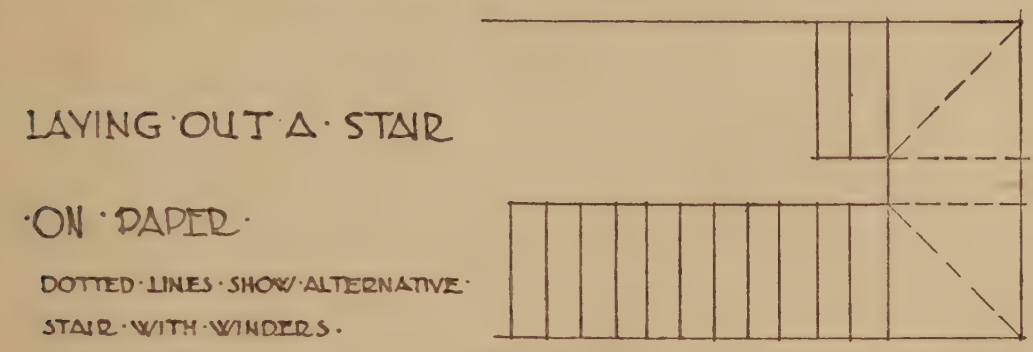


Fig. 164

The next step is to mark off on a vertical line extending from floor to floor corresponding to the story rod 15 divisions, for which the following is a rule-of-thumb method quickly executed. Lay the scale at an angle so that the figure 0 on the scale coincides with the lower floor line and the figure 15 with the upper floor line, and tick off on to this

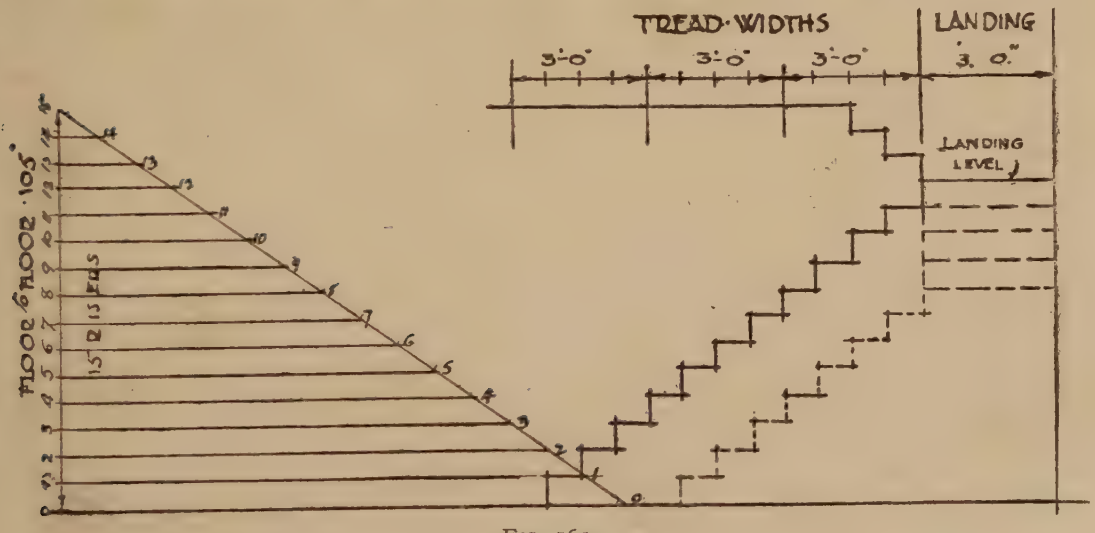
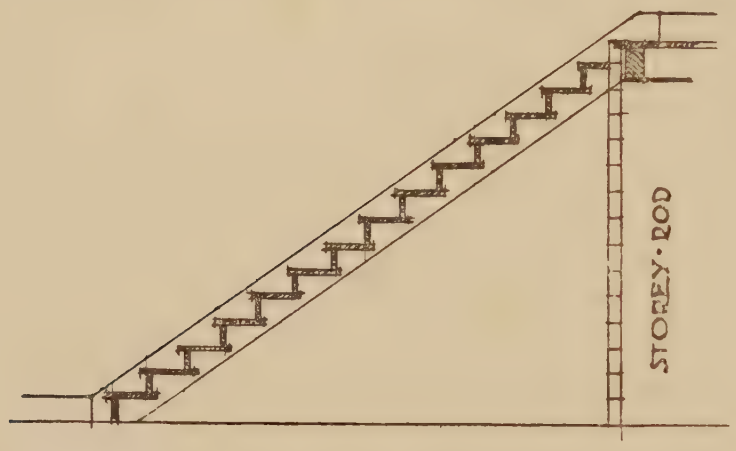


Fig. 165.

diagonal line the numbers 1 to 15, when lines drawn parallel to the bottom floor line from 1 to 15 will give, where they cut the vertical line, the risers in equal heights, 0 being the lower floor and 15 the upper. In actual draughtsmanship it will save time if the vertical line chosen be the outer wall of the stairs; and if an open newel stair has been decided

upon, with a landing of at least 3′ 0″ from this wall to its outer edge, this should be provided at a height giving suitable headroom as already described. A distance of 3′ 0″ may then be marked off from the outer wall at the height chosen, and from that point distances of 9″, which, for expedition in drawing, it will be found convenient to set off in distances of 3′ 0″ subdividing into 4 subsequently. In this it should be borne in mind that the top step of each flight being the surface of the floor, or landing, consequently the number of treads will always be one less than the number of risers; so that, if the landing is at the height of 12 risers, 11 treads will require to be marked off from the outer edge of the landing. This will give the flight from the landing to the lower floor. As a time-saving method the depth of landing and 11 treads of 9″ may be ticked off from the scale laid along the line of the upper floor, in which position they will not be hidden from view by the T square in completing the flights, but the risers may be drawn down from them by the use of the set square. Starting, then, with the outer edge of the landing as the 12th riser, the remaining treads and risers may be drawn alternately by the use of the T square for treads and T square and set square for risers until the flight from lower floor to landing is completed. The upper flight may then be finished in the same manner, working upwards from the landing, the outer edge of the landing continued upwards for a height of 7″, being the first riser from the landing or the 13th in the stairs.



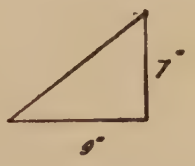
SHOWING USE OF STOREY·ROD·

Fig. 166.

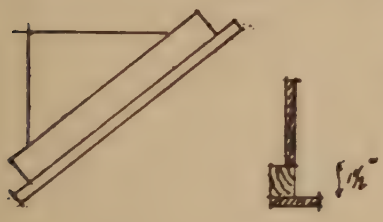
From this skeleton section so formed the plan may be completed and its relation to the floor space, doors, etc., on both floors studied. And where another staircase is desired above the section should be worked out in the same manner, in order that the necessary headroom may be obtained and its effect upon the plan discovered before the other details of the plan are filled in. In upper flights, where they come under the roof, it is always advisable to design the stairs so that the topmost flight follows the rake of the roof, but where headroom is not possible dormer-windows cut in the roof will supply this.

Where winders occur, though showing in their actual position in plan, on the skeleton section they will appear merely as vertical spaces left vacant, the first rectangular tread starting from above the line of the outer edge of the landing at the height of the mark, indicating the top winder.

LAYING OUT A STAIR IN THE SHOP.—In the actual construction of the stairs in the shop a story rod is used, which corresponds to the vertical line on which the heights of the risers were marked off in the drawing. In the same way the heights of the risers are set out on the story rods by means of compasses, the proportion of tread to riser having been determined by any of the methods already described. The story rod is first marked on the works with the distance from floor to floor by being dropped vertically down the face of the trimmer to the floor below to a point directly under it obtained by means of a plumb-line and bob. The point at which the floor boards on the upper floor cut the story rod is then marked on the story rod, which is now divided equally by means of dividers into as many divisions as there are risers shown on the drawings. The top one is then marked UP and the side of the rod on which these divisions figure is marked RISE. The rod is next laid against the plaster of the end wall if the wall is rendered, or 1″ is allowed if it is not, and the distance from this end wall to the trimmer position is marked on the other edge of the rod. The position of the first riser is also marked on the rod, and should be lettered START. The position of any openings for doors or windows should also be marked.



PITCH BOARD
FIG. 167.



PITCH BOARD WITH MARGINAL STRIP.
FIG. 168.

From the story rod the heights of the risers are marked on the inner faces of the strings on a line drawn 1½″ from the bottom edge of the strings and parallel to it.

The next process is to get out a template, known as a "pitch board," for laying out the form of the steps on the strings. This template is shown on Fig. 167, in the form of a right-angled triangle having a base the width of the tread and a height the same as that of the riser. The pitch board is then laid on the string with its longest side along the line marked 1½″ up from the bottom edge and with the side of the same length as the tread touching the point marked from the stair-rod, the third side giving the face of the riser.

An alternative form of pitch board is that shown in section in Fig. 168. On the bottom edge of this is fixed a strip of the same width as the margin,

and another strip is tacked on at right angles to act as a gauge for the pitch board to enable the correct angle of the lower edges of the rise and tread mortises to be marked on the string. It might be thought that the simplest method would be to mark out the tread and riser at right angles; but, as the mortise has to be of wedge shape to take the wedging at the back of the treads and risers, the angle between the two mortises make 98° instead of 90°. For use in conjunction with these two other templates are required, the one —the riser template—being the length of the riser and its width plus the space required by the wedge, the other—the tread template—having similar dimensions. These are then laid on the single lines marked on the inner faces of the strings from the pitch board, and a line drawn round them gives the actual dimensions of the chase mortises into which the treads and risers are to be housed and wedged.

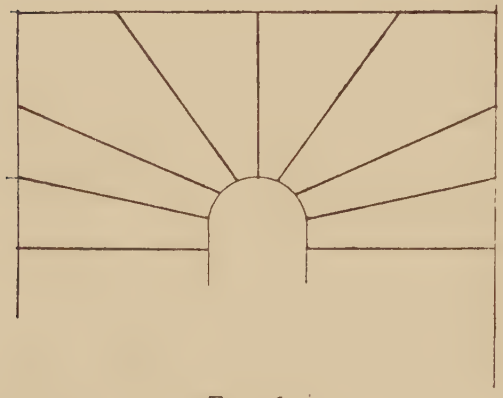
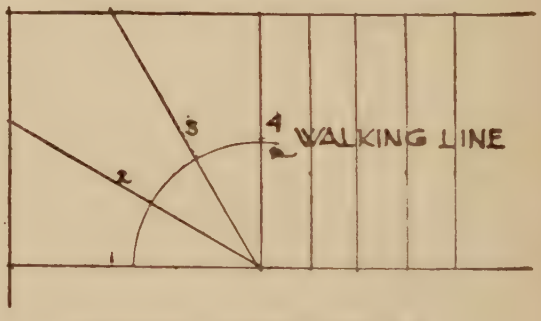


Fig. 169.

The length of the string may be estimated by multiplying the longest edge of the pitch board by the number of steps, adding the distances necessary to meet the skirtings, or return strings, though it is advisable to leave an additional length for cuttings and fitting on the works.

A more rough-and-ready method of laying out the steps on a string is by the use of the steel square on which the inch marks, corresponding to the depth of tread and riser, are placed against the line parallel to the bottom of the string.



LAYING·OUT·WINDERS·1

Fig. 170.

Laying out Winders.—When winders occur at the bottom of a flight they are laid out in the following manner. One leg of a compass is placed at the outside end of the last rectangular riser and the other leg opened out to 18″ and a curve described between the point where it cuts the last rectangular riser and the bottom riser at right angles thereto. This curve is then divided into three equal divisions, and through these points lines are drawn from the centre of the curve to the wall string. These lines give the risers of the winders.

To lay out the wall strings to take the winders, they are measured from the fourth riser to the third, the distance between the points where the fourth and third risers cut the wall string on plan. One leg of a compass is placed on the angle of the fourth tread and riser and the other leg to the top edge of the straight string. An arc of the same radius is then described from the point of intersection of the tread and riser No. 3 with the string. A tangent to the two arcs gives the top edge of the string and line parallel to this and at a distance sufficient to take the second tread gives the underside of the string.

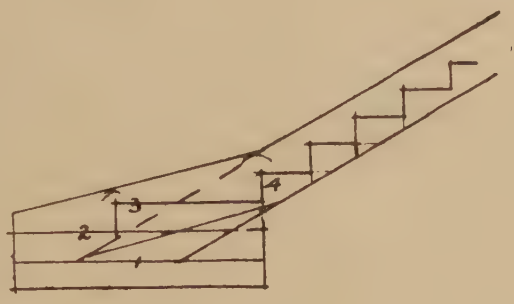


Fig. 171.

To obtain the short string on the wall at right angles to the main flight, take the first riser and part of the second, draw riser 1 at a point where it cuts the string and the same with riser 2, making the distance between them equal to the width of the first winder and the distance from the top of riser 2 to the string equal to that portion of the second tread which is carried by this string. The height from this intersection of the second tread with the string to the top of the string should be made equal to the height of the point of intersection of the wall string described in the last paragraph to take winder No. 3.

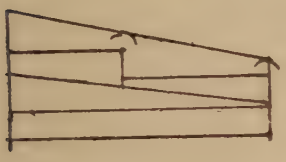


Fig. 172.

Risers Around Cylindrical Openings.—The ends of well holes between flights are often terminated in a cylindrical curve around which the winders are formed. By this means the narrow ends of the winders are prevented from coming to an actual point, as when grouped round a central newel. Considerable work will be saved by their correct arrangement in the construction of the strings and rails.

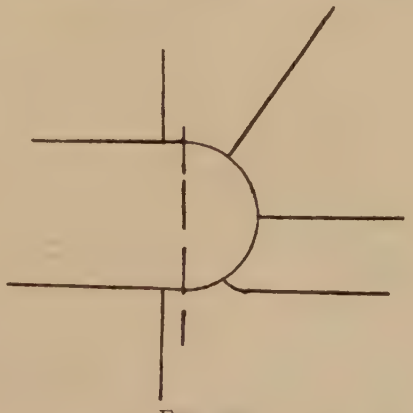


Fig. 173.

Where there are several risers around the cylinder the chord of the arc should be drawn and the riser of the last rectangular riser should be so placed as to come 2″ below this chord, as in Fig. 173. Where a cylinder is placed either at the top or bottom of a staircase, and contains several winders, the one next the landing should be placed at least 2″ within the cylinder, when the remaining winders should have

their risers radiating at equal distances apart from the centre of the cylinder.

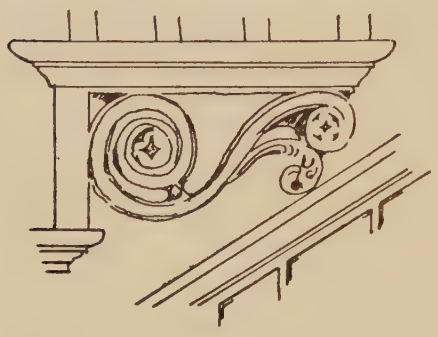


Fig. 174.

Where the cylinder comes at the intersection of two flights leading from a half space or level landing the diameter of the cylinder should equal the width of the treads and the risers should be in the springing.

Definition of Parts of Staircases

Stairs consist, in their simplest form, of two parallel bearing timbers known as *strings* placed at an angle from the point of departure to the point of arrival, having the space between them filled in with boards forming rectangles, having the upper surface horizontal and the upright surface vertical.

The horizontal surface, being the portion stepped on, is termed the *tread* and the vertical face is known as the *riser*.

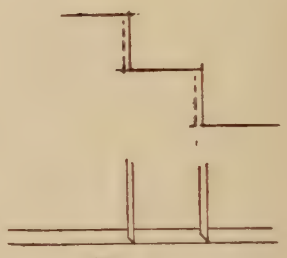


Fig. 175.

Of the side supports, or *strings*, that against the wall is known as the *inner*, or *wall string*, and that farther from the wall is termed the *outer string*.

Outer strings are sometimes notched out on their upper surface to conform with the tread and riser of each step, their lower edge being parallel to the slope of the stair, as in ordinary solid strings. Such notched strings are known as *cut strings*, and in all but the cheapest work the vertical portion of the notch is cut splayed and the riser mitred therewith, by which means the end grain of the wood is concealed. The string is then termed a *cut-and-mitred string*. Cut strings are generally of greater thickness than ordinary solid strings, being $2\frac{1}{2}''$, and have the effect of saving the *carriages*, described later. Cut strings in newel stairs are mortised and tenoned into the newel posts at the top and bottom.

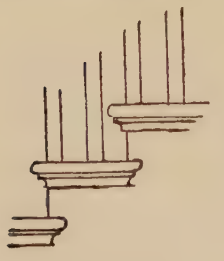
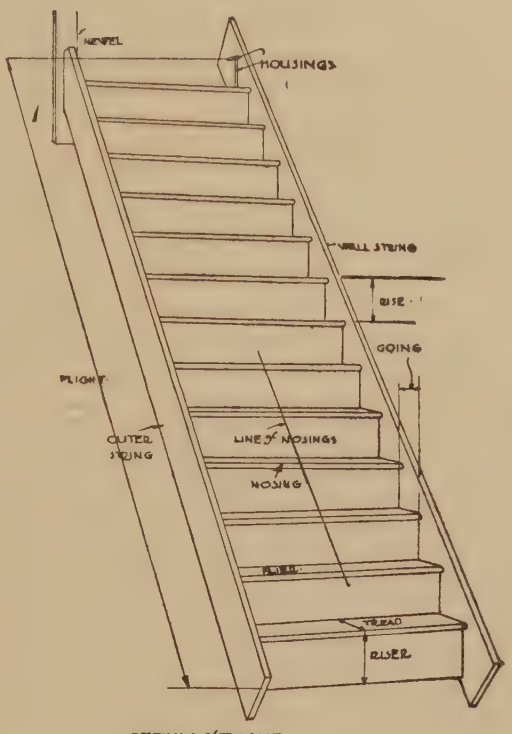


Fig. 176.

Housed Strings.—Solid, or closed, strings have both upper and lower strings running parallel to the slope of the stairs, and housings or grooves are cut in their inner faces to receive the ends of the treads and risers. The method of cutting the housings, or grooves, is as follows. After the steps have been marked on the face of the string as has been already described, the next operation is the marking of the underside of the grooves for the treads

and the inner sides of the grooves for the risers to a shape suitable to take the thickness of the treads and risers, together with the wedges which are driven in and glued for stiffening.

As has been indicated, two thin templates are prepared, a riser template and a tread template, and applied to the lines of the steps already drawn on the inner faces of the strings. A brad-awl hole is made in the centre of the nosing of one of the treads so that the template may be held in position by means of a brad-awl passing through the hole. The riser template is pushed up against the tread template, having its outer edge coinciding with the line already drawn for the outer face of the riser. The underside and inner side are then marked round and the shape of the grooves obtained on the strings. The grooves are then cut by means of a brace and bit having its centre placed in the brad-awl hole, when a rounded sinking is cut, the outer half of which becomes the grooving for the nosing of the tread. Then one or two further circular borings are made with the same bit for both tread and riser, being so placed that their circumference is tangential to the outer faces of both tread and riser. The intervening portions of wood left are then chiselled out, by which a portion of the tread and riser groove is obtained at the nosing end of the tread and its junction with the riser. This preliminary boring, besides giving the rounded sinking for the nosing, permits of the use of the tenon saw for the cutting of the rest of the lines marked.



DETAILS OF FLIGHT
FIG. 177.

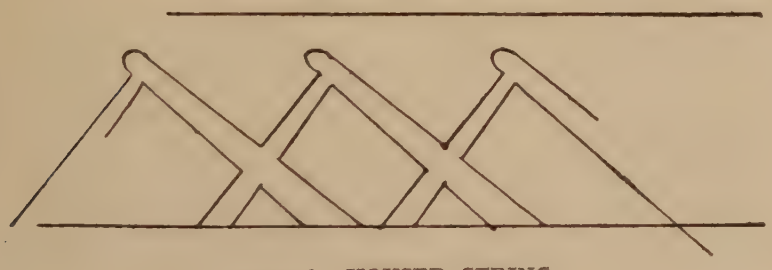


FIG. 178.—HOUSED STRING.

The tenon saw used is that known as a *stair-builder's saw*, which is of

the type shown in Fig. 179, and has a raised point on the back for the left hand to rest upon. The wedge-shaped grooves having been cut top and bottom, the intermediate wood is removed by a chisel, and the grooves are then smoothed by the use of a *router plane*.

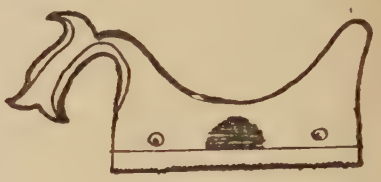


Fig. 179.

The finished string, with a tread and riser in position, then bear an appearance as shown in Fig. 181, the wedges being shown driven in and glued.

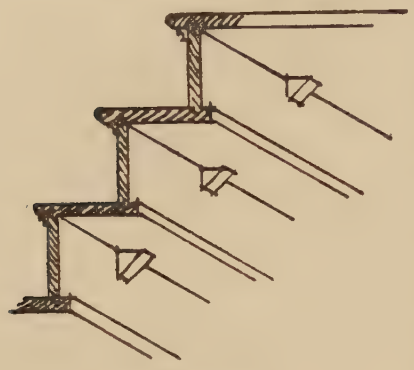


Fig. 180.

Wreathed Strings are the curved portions around a cylinder of the outer string in geometrical stairs. It should be cut out of stuff at least 2″ thick. Figs. 182 and 183 show the method of bending and cutting the curved piece of the string around a drum built up of narrow strips glued together on a frame. The wreathed or curved part of the string is either a veneer or made by cutting away all but a thin outer surface of the string until only a thin veneer is left. After this has been bent upon the drum, or framed cylinder, battens, wedge-shaped, are glued on to bring it up to its original thickness and to maintain its new bent shape. After the battens or keys have set, the curved string is cut for treads and risers. In Fig. 182 the elevation and plan are shown of a string prepared for bending, the string being marked for treads and risers before it is bent round the drum, and it is necessary to prepare and lay out a pattern or template of its true form, as is shown in Fig. 184.

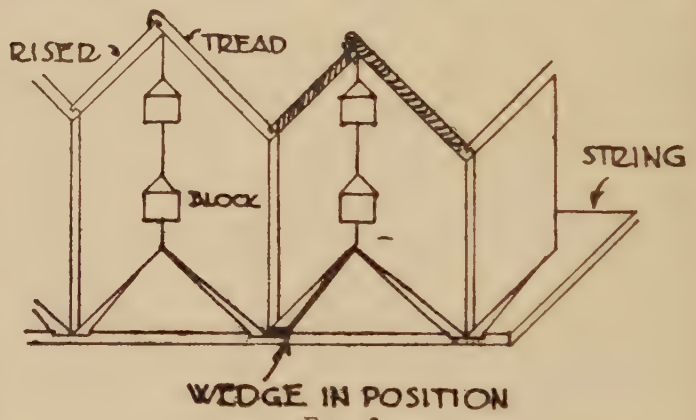


Fig. 181.

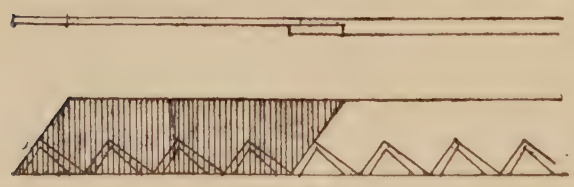


Fig. 182.

A semicircle, 1, 2, 3, is described having the same radius as the cylinder, and then, with 1 and 3 for centres and 3, 1, for radius, arcs are described which cut at 0. From 0 draw a line through 1 to 4, and likewise through 3 from 0 to 5. The distance from 4 to 5 indicates the length of the true length of the semicircular curve 1, 2, 3. The risers 13 and 14 are next dropped vertically to where they cut the line 4, 5, and the points of intersection marked 6 and 7. From 4, 2 and 5 draw up vertical lines and upon the line draw from 13 to 6, set off from 6, the height of two risers at S and 13. From the point 13 draw the line 13Z horizontally, and from Z measure vertically the height of one riser, marking the end of the line 14. Next, from S draw a line to 12 and set off from 12 to *h* the height of one riser; from *h* draw the horizontal *h* 11 to give tread No. 11, and drop a vertical from 11 to the pitch line to give the riser of No. 11. Continue the pitch line from *h* to *s*, and the pitch of the upper flight from 15 to 16. Next draw lines $1\frac{1}{2}$ below the pitch lines so formed and parallel thereto. Take the distance from 15 to this line with the compasses and describe arcs with centres at *s* and *z*, join the intersection of these two arcs with the bottom of the string with a freehand curve tangential to the arcs. Then draw a line through 14 and 12, and at 12 and 14, at right angles to this line, drop lines down to 15 and *h*. The pattern then formed gives the form for cutting treads and risers bent around the concave face of the cylinder.

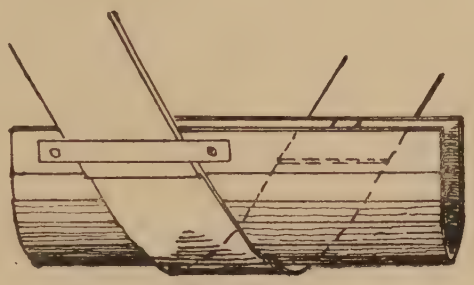


FIG. 183.

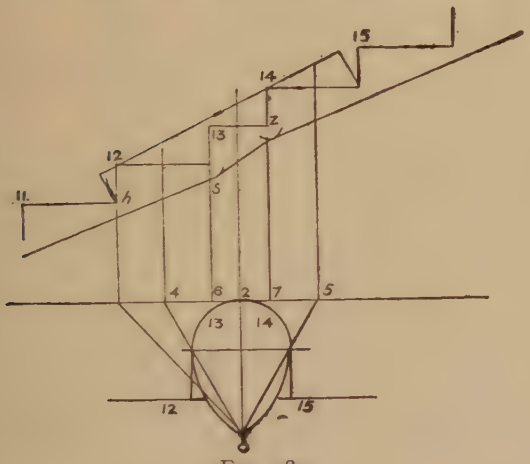


FIG. 184.

CARRIAGES, sometimes termed *rough strings*, are placed in between the inner and outer strings and run parallel to them from floor to trimmer. They are used to give intermediate support to the steps, and add very considerably to the stiffness of the stairs. Their underside provides a fixing for the laths where the soffit is plastered, in which case they should be spaced apart not more than 15″ on centres. Creaking stairs denote either the omission of carriages or that the carriages are too weak, and sag when weight is put upon them. They should be of a size not less than 2″ by 3″, but are better 3″ by 4″, and are formed out of rough unplaned

stuff. Sometimes the carriages are cut to the angle of the treads and risers, so as to fit tightly under the treads and against the inner faces of the risers; but more often they consist of straight timbers of the sizes mentioned, having 1″ to 2″ cleats nailed on their sides to support the treads. This form, necessitating no cutting of the carriage, is consequently stronger. In very economical construction the carriages are omitted and the soffit of the stairs is prepared for plastering by having strips nailed to the lower angular intersection of the steps.

STEPS.—The steps, being composite, consist of a horizontal surface upon which the foot rests, known as the *tread*, and a vertical, known as the *riser*. The treads and risers are mortised and tenoned, rebated and grooved or housed together and housed at their ends into the strings.

FLYERS.—The parallel rectangular steps in a geometrical stair, as distinguished from irregular shaped steps such as winders, dancing steps, commode steps and curtail steps, are termed flyers. Diminished flyers

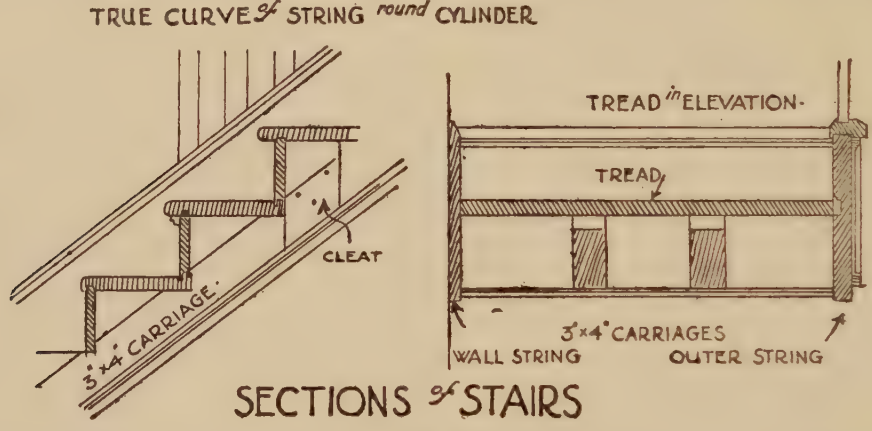


FIG. 185.

are those steps next above and below dancing steps, which are narrowed at one end only in order to permit the extra width necessary to enable the centres from which the risers of the dancing steps are struck to be obtained.

WINDERS are steps the risers of which radiate from a central point of a single newel post or from the centre of a cylinder. They are found necessary for the purpose of gaining extra height of ascent with a saving of floor area used. In newel stairs the inner ends of the winders are housed into the newel posts. As the carriage is stopped by the *pitching* piece and cannot be continued to carry the winders, they are supported by means of bearers built at one end into the staircase wall and framed into the newel at the other. The bearer at the back is flush with that of the riser immediately over it. Cross bearers to support the treads are framed between the risers and the bearers behind them.

Bearers framed round a cylinder, as in geometrical stairs, have a *wreathed string* and cross bearers similar to those used in a newel stair.

In connection with winders, the *walking line* is a term used for an arc of a circle having the newel as centre and 18″ as radius upon which the winders are set out on plan.

As has been said, winders should only be used where it is desired to be economical of floor area. They increase the cost of construction, being more complicated, and where several are formed radiating from a central newel they are dangerous on account of the vertical drop formed at the newel. A rule of thumb for safety is that the width of the head of a winder at the walking line should never be less than the width of an ordinary rectangular tread in the straight flight.

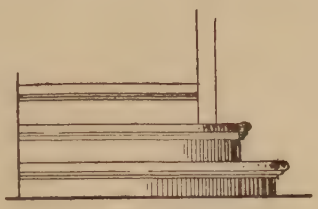


Fig. 186.

Dancing Steps are winders that do not radiate from a common centre. They are provided to overcome in some degree the danger occasioned by having a direct vertical drop of several risers in the height of the newel post. They are sometimes termed *balanced steps*, being then diminished fliers having their outer end narrower than the inner, or wall end. They are useful also for easing the break between winders and fliers.

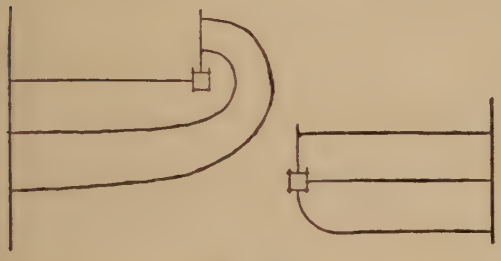


Fig. 187.

Commode Steps are those the plan of which is a parabolic curve, and is often met with in the bottom step or steps of a geometrical stair.

A Bull-nosed Step is one with a rounded quadrant, or hexagonal end. The ends of these and curtail steps are formed of shaped blocks made up in three or four thicknesses or built up blocks covered by the riser face cut to a thick veneer. The joint is secured by wedges and by the block being screwed to the thick portion of the riser, as shown in Fig. 189.

Such stairs are often fixed in hall-ways where an improved appearance is desired, the newel being placed on either the first, second or third riser. One method of bending these risers is that shown in Fig. 188, where a solid block is prepared to support the veneer, as mentioned above. The solid portion of the riser is screwed to the block at *b*, the veneer being bent round the block to *a*, at which point the space left is tightened up by two wedges driven in tightly to clamp the veneer to the block after the back of the veneer has been covered with glue.

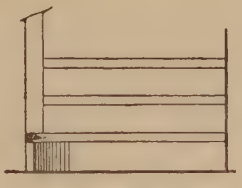


Fig. 188.

In another method the veneer extends to the end of the curved portion, as at *b*, and in place of the block supports or shoulders are framed up in

sections and nailed together to the form required. The veneer is kept in position whilst being glued up by means of hand screws, though, where these are not available, as when the work is done out of the shop, it is fastened by means of cleats nailed to the form, pressing the veneer tightly all round.

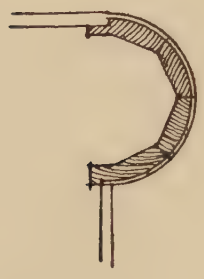
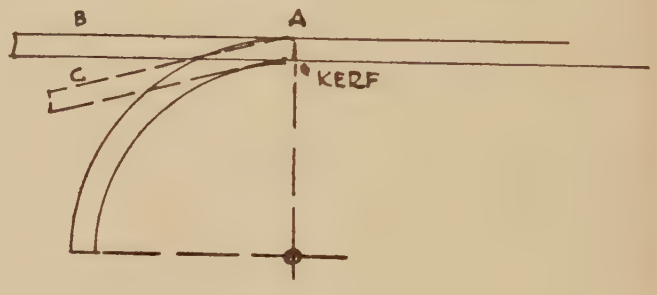


Fig. 189.

To prepare the end of the riser for bending by a third method known as " kerfing," saw cuts at equal distances are made on the inside of the riser to leave a thickness uncut on the face equal to the thickness of the veneer left as already described. To find the distances between the saw cuts which will guarantee the best results in bending, the method is as follows. A cut is made at the first point of bending, and marked *a* in Fig. 190, and from *a* along the portion to be bent, marked *ab*, equal to the radius of the curve desired. Next bend the wood as far as it will go from the cut at *a*, when the new position of *b* is marked as *c*, and the distance between *b* and *c* gives the distance apart at which the *kerfs* should be cut.



KERFING

Fig. 190.

A better method than those described to bend risers and strings is that known as the laminated method, in which the piece required to assume a curve is made up of thin layers of $\frac{1}{8}$" thickness bent round a drum. Between each layer there is a coating of glue, and the layers are pressed together by means of hand screws, or cleats, and left round the drum to set.

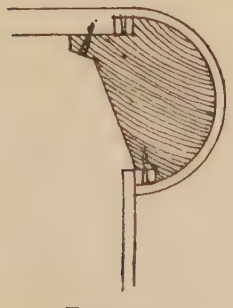


Fig. 191.

Yet another method of bending the riser of a bull-nosed step is that shown in Fig. 191, where the veneer is bent round a shaped block. This block is prepared to the shape desired on plan and built up in three thicknesses, which are glued and screwed together. Rebates are cut in each side for the housing of the riser face, that on the newel side being undercut. The distance of the springing from the newel end on the riser, which is cut out of a piece of pitch pine free from knots, is then marked. The rebate in the block is then placed on this mark, and rolled round carefully on the back of the riser, and when the opposite rebate

is reached its position is also marked, an allowance for wedge room being made. The material in between these marks, allowing $\frac{1}{8}$" for veneer, is cut away with the hand saw and chisel. Two screw-holes are then bored in the corners of the blocks, and, after the face of the veneer has been well wet with boiling water, the block is fixed and glued into position by rolling the veneer slowly round it, pressing down until the end is reached. Wedges are then driven into the space allowed to bed the veneer tightly and the screws are driven in.

TREAD.—The tread is the horizontal board on which the foot rests in passing up or down the stairs. It is made out of $1\frac{1}{2}$" stuff and is housed into the strings at its ends in the manner described above.

RISER.—The riser is the vertical board supporting the tread, cut out of $\frac{7}{8}$" stuff and housed into the strings and notched into the carriages.

The treads and risers are mortised into each other, the tenon at the top of the riser being kept at the back of the riser, and a cover mould to hide the joint is inserted under the nosing.

The bottom of the riser is tenoned into the back of the tread, the tenon being in this case cut on the front edge of the riser and the tread extended beyond the back face of the riser.

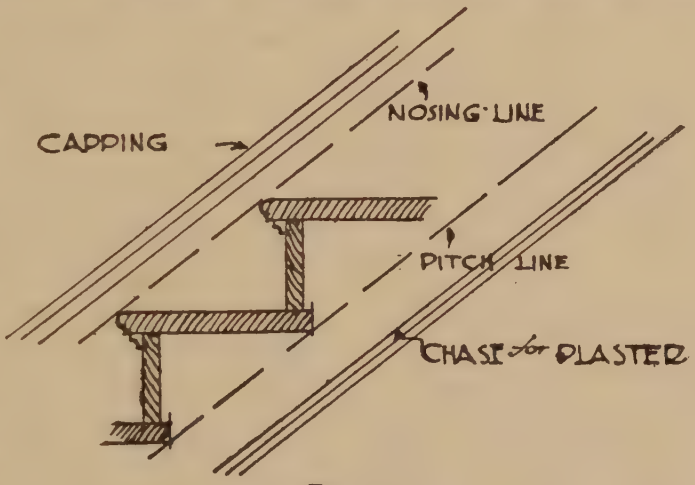


FIG. 192.

RISE.—The rise is the vertical distance between the upper surfaces of two successive treads.

THE GOING is the horizontal distance between the faces of two successive risers as distinguished from the tread, which includes THE NOSING, which is the outer edge of the tread projecting beyond the line of the face of the riser produced upwards. The nosing is either rounded or moulded to save wear on the carpet, and generally has a cavetto mould, or $\frac{1}{4}$ round bead mould, to cover the joint. This mould is frequently let into the underside of the nosing and butts against the riser face.

MARGIN is that portion of the string which rises above the line tangential to the nosings of the treads, and is generally formed in part by a capping mould housed over the top of the string into which the balusters are housed or tenoned.

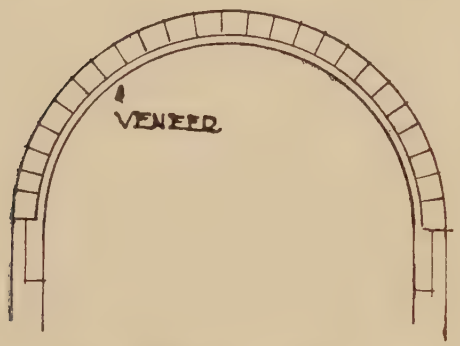
OPEN STRINGS are also called cut strings, and have their upper edge cut out to line with the treads and risers of each step, their lower edge

being parallel with the slope of the stair, as with closed strings. With open strings the balusters are dovetailed into the treads, the treads being prepared to receive the dovetails on the balusters and cut on the nosings to mitre with the return nosing.

Housed Strings are also termed closed strings, and have their upper and lower edges parallel with the slope of the stair. The portion above the line of the nosing is termed the *margin*, and that below the line of the backs of treads, known as the *pitch line*, is projected to receive the battens for lathing to, and has a splayed chase to conceal the joint of the plaster and string, the outer string being cupped underneath by a moulding housed on to its bottom edge.

The strings are housed out in their inner faces to take the ends of the treads and risers in the manner already described.

Wall String.—Where strings come against walls they are termed wall strings, and where one comes against a wall and the other is free the distinction is made by terming them *inner* and *outer strings*. The portion of the wall string above the steps is cut to line with the skirting running round the landing and at the bottom of the flight a shoulder is formed to serve the same purpose the strings being halved, mortised or mitred to fit into the skirting.



WREATHED STRING

Fig. 193.

Carriages are sometimes termed *rough strings*, and are the intermediate supports of unwrought timber 2½″ to 3″ deep, placed at not more than 15″ apart from centre to centre, and notched out to receive the angles of the treads. To their underside are fixed laths to take the plaster of the soffit. As an alternative to notching the upper edges of the carriages rough brackets are nailed to the sides of the carriages to fit up against the underside of the treads and against the backs of the risers. At the top and bottom ends of intermediate flights the carriages are birds-mouthed to the trimming joists and bolted to splayed pitching pieces.

A Wreathed String.—The strings as a rule terminate in newel posts, but in a geometrical stair they are frequently bent round into a cylindrical shape at the landings and splayed out at the last two or three steps on the ground-floor level. It is then termed a *wreathed string*, which should be at least 2″ thick and may be close or open. The method of bending has already been described, and it is sometimes strengthened by a flat iron bar being screwed to its bottom edge.

The Soffit is the underside of the flight, which may be plastered, matched-boarded, panelled or left plain, in which case the woodwork will need to be wrought and stained, wax-polished, or painted.

CAPPING.—Housed over the outer string is a moulded or chamfered capping into a groove in which the feet of the balusters are tenoned, or alternatively it may be mortised or dowelled to the feet of the baluster. The wall string has a half capping of the same design, with a rebate or chase on the back to cover the joint with the plaster.

The capping, where there is a newel, is housed into it on the outer

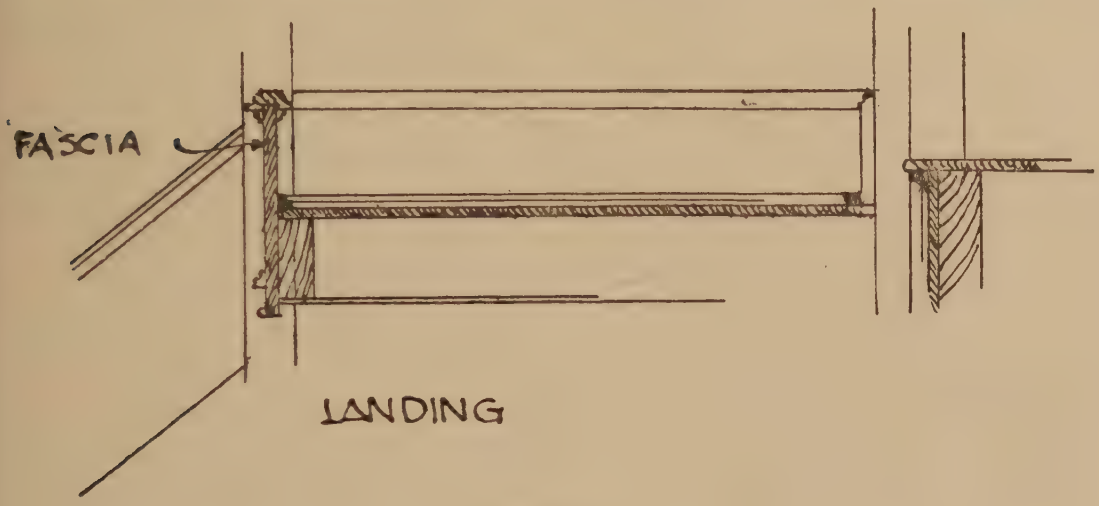


FIG. 194.

string and on the wall string, though the best finish is to insert a half newel at a parallel position to that on the landing. This method is often omitted on account of expense, when the capping must be scribed to fit the skirting.

The width of the capping will depend on the design of the outer string and the size of the feet of the balusters.

On landings the string may be continued at a height equal to that of the skirting, in which case the capping will form its top member, or the capping only may be run along over the floor boards, which are projected out beyond the outer string, which then becomes a fascia and the ends of the floor boards are cut away, having a rounded or moulded nosing cut in and fitted under the capping.

FIG. 195.

Where the floor is trimmed at the top of the flight a fascia is fixed to the face of the trimming joists to line with and having the same detail as the outer string, and the capping may be treated in either of the ways described for landings.

LANDINGS.—A landing is the level space provided in the ascent of a staircase to serve as a rest, and also to provide a change in direction,

and at the same time to save the area of floor space occupied by the staircase.

As has been stated, a staircase in one flight and in one direction of ascent may be broken by a landing at any height that is found convenient. Such a landing is termed a *quarter space* landing; but where the landing is desired to serve as a turning place, and is extended across the whole width of the staircase well, it is termed a *half space* landing.

For its construction a trimmer is fixed across the width of the staircase

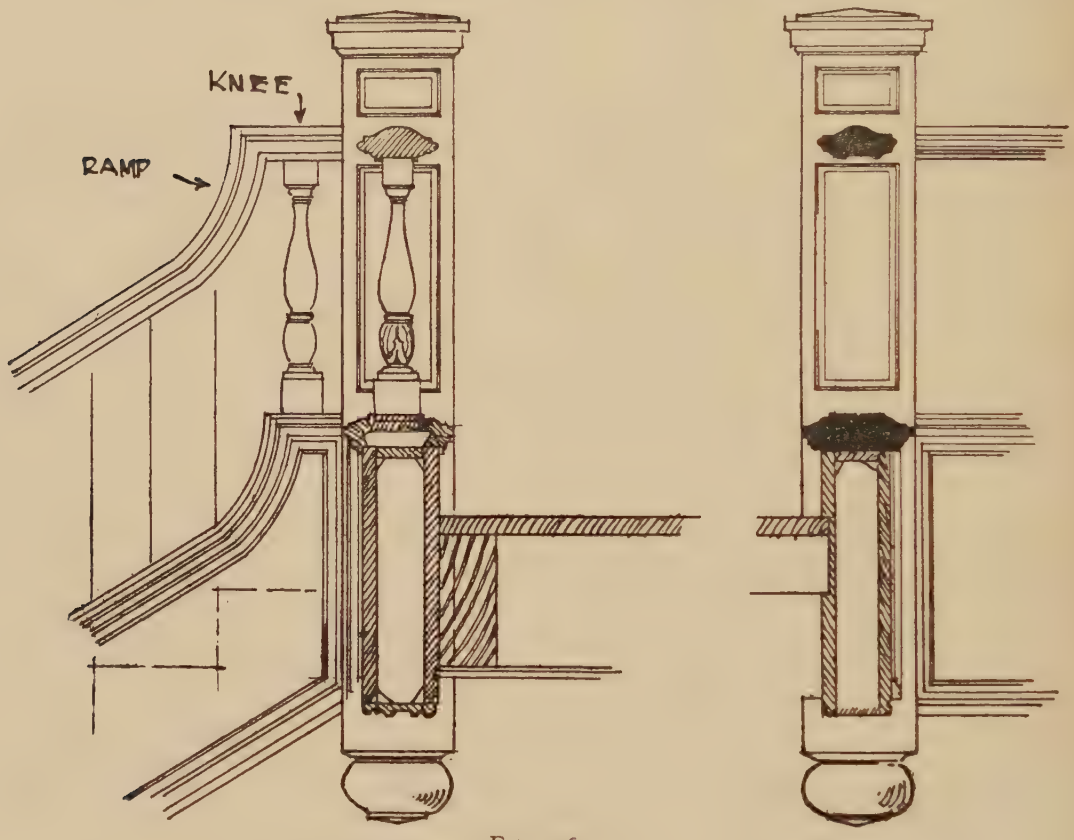


Fig. 196.

and supporting bridging joists, which may be of smaller dimension than the floor joists according to the span. The bridging joists are tenoned into the trimmer at one end and rest on the wall at the other. The newels are notched over the trimmer and take the ends of the carriages.

Winders are often introduced in the place of landings, and a half space landing may be divided by one or more steps into two quarter space landings; but where economy is studied the practice should be avoided, and the introduction of one step into a landing should never be permitted unless no alternative is possible, as, apart from the danger

arising from the unexpectedness of one step, the additional cutting and corners necessitated are out of proportion to the convenience gained.

In larger houses, hotels, etc., landings are sometimes extended across the width of a hall, when they become galleries, and in such positions are often bayed out, as in the musicians' gallery of the mediæval hall.

In staircases having the bottom flight divided into two running in opposite directions a quarter space landing is introduced at their junction, and the flight continued in one.

THE WELL is a term used for either the whole space set apart for the staircase, when it is termed either the *stairway*, or *staircase well*, or it applies to the space between the outer strings of two adjacent flights going in opposite directions, when it is termed simply the *well*, or *well-hole*.

A STAIRCASE is the term applying to the whole erection composed of one or more flights, by means of which ascent is gained from one floor to another or to several floors.

STAIRS are distinguished from open treads, as seen in the rungs of a ladder or in fire-escapes having no risers, by being closed in on their underside and backed in by risers.

The GOING of a tread is the horizontal distance from the face of one riser to that of another as distinguished from the *going of a flight*, which is the horizontal distance between the faces of the bottom and top risers of that flight.

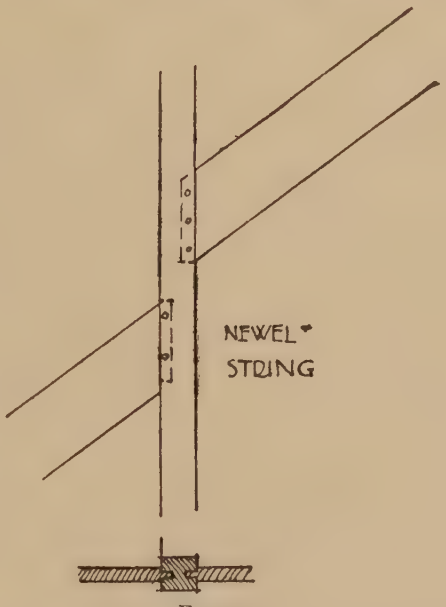


FIG. 197.

The WALKING LINE is an imaginary line on the stairs or an actual line drawn, with the newel as centre and 18″ as radius, on which winders are spaced out on the working plan.

A NEWEL, OR NEWEL POST, is a squared or turned upright post at the bottom and top of a flight into which are run the outer string and handrail. It may be of a height sufficient only either to finish flush with the handrail or just to rise above it, or it may be carried up to the flight above, or again, as in a circular stair, it may run from top to bottom of the staircase.

Newels may be framed up, panelled and carved elaborately, and, where a narrow well hole is left between two flights instead of two ordinary newels, one broadened out to take both handrails may be introduced with effect and saving.

The heads to newels may be left square, or moulded, and finished with balls on moulded bases or carved with fingers.

A Mitre Cap is the moulded top of a newel post into which the handrail is mitred in cases where the handrail itself forms the top of the newel.

Where a wide handrail is employed a newel may be composed of four balusters set in a square supporting the handrail embossed out.

A Handrail is a guard at the side on a stair run at an angle parallel to the rise of the flight at a convenient height for the hand to rest upon, generally at from 2′ 4″ to 2′ 6″ above the nosing of the tread. It is housed at its ends into the newels and into a chase cut in its underside are housed the balusters. Handrails on landings should have a height from 2′ 8″ to 3′ 3″.

A Mop Stick Handrail is one circular or horseshoe shaped in section, and is generally made of oak or other hardwood wax-polished.

A Ramp is the name given to the concave curve in a handrail necessary to raise its height more rapidly than would be achieved by following its general line of rise, as when it comes against and forms part of a newel cap on a staircase landing, in which situation a handrail is run at a higher level than on a stair. For ornamental purposes handrails are sometimes ramped so as to enter the newel post at a level equal to that of the handrail across a level landing. They are likewise ramped at the bottom of the length to enter the bottom newel on the level.

Fig. 198.

A Knee is the reverse of a ramp, being a convex curve in a handrail.

When a knee follows upon a ramp the resultant curve is termed a Swan's-neck.

A Scroll Wreath is the term given to a termination of a handrail in a spiral supported by one or by several clustered balusters. It is struck from a variety of centres, and is frequently found over the curtail step of a geometrical stair. A vertical scroll at the end of a handrail is known as a Monkey-tail.

Square Cut is the term used in description of the modern method of forming a handrail wreath, in distinction from the older method known as the *Bevel Cut System*. In the first the wreath is cut square from the surface, whilst in the *bevel cut system* the edges of the wreath are cut to a bevel.

The Tangent System is a geometrical method of obtaining the true section of a cylinder or other symmetrical solid when cut by an inclined plane, as in a handrail wreath, by enclosing the solid with tangent planes upon the surfaces of which the inclination of the plane is drawn.

Tangents are lines or planes, touching a curved line or surfaces, but not penetrating.

The Springing is the term applied to that portion of a handrail where a curve commences, and the term is also applied to a similar portion of a string.

A Core is the name given to a thin bar sunk and screwed into the underside of a slender handrail to stiffen it.

Balusters are the intermediate supports to a handrail between the newels. They are tenoned into the capping of the outer string at their lower end and housed into a groove in the underside of the handrail at their tops.

The Pitch of a Stairs is the term signifying the angle of the line drawn tangential to the nosings of the treads makes with the horizontal.

Timbering is the name given to the under-framing of rough supports of a stair.

A Pitching Piece is the name given to a piece of quartering fixed between the wall and newel on the underside of winders and into which the carriages are framed.

A Trimmer is the joist carrying intermediate joists forming a landing or carrying the ends of the joists cut to form the staircase well.

A Fascia is the vertical wrought board affixed to a trimmer round a staircase well.

How to lay out Easements

Where, owing to there being landings and newels on stairs, the line of handrail, if continued, would cut the newel at different levels, curves known as goose-necks and easements are introduced to effect the entrance of the handrail to the newel at the same horizontal height.

In Fig. 199 is shown how to lay these out. The line of the handrail of the top flight would, if continued, strike the newel at *a*, and the rail of the handrail of the lower flight at *b*.

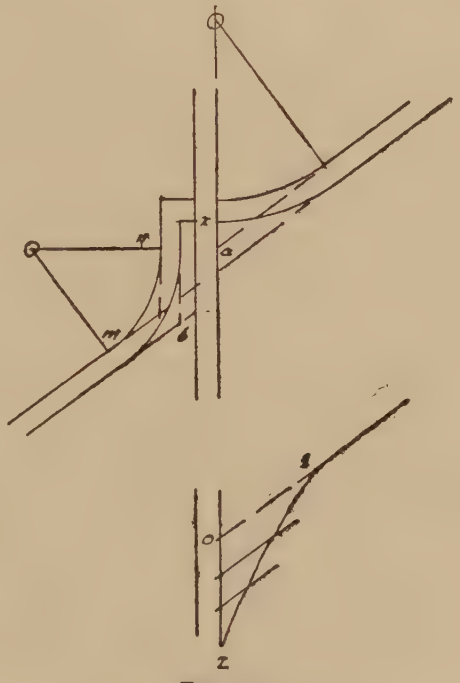


Fig. 199.

To describe the curve of the upper section take a point *x* at any distance desired above the intersection of the handrail line and the newel and draw a horizontal line *xy* calling the point where it cuts the lower line of the handrail *y*. From *y* as centre, with radius *yx*, describe an arc, calling the point at which it cuts the upper line of the handrail *z*. Next produce the line of the face of the newel, cut by the handrail line, and from *z* draw a line at right angles to the line of the handrail until it cuts the vertical line of the newel produced, calling the point of intersection *o*. Then, from *o* as centre and *oz* as radius, describe an arc which gives the top of the handrail as desired. A parallel curve of the same width will give the bottom line of the curved handrail.

Next, from a point horizontal to the points at which the new curve

strikes the newel, draw horizontal lines the top one of which has a length of from 5″ to 6″ according to the depth of the handrail, so as to leave a clearance between the underside of the handrail and the newel post. This forms the portion known as the knee. From the ends of these drop vertical lines to cut the line of the handrail, at *c* and *b*. With centre *c* and radius of any convenient length, calling the point *n*, describe an arc, *cnm*, calling the point where it cuts the line of the handrail *m*. From *m* draw a horizontal line and from *m* draw a line at right angles to the line of the handrail, calling the point where these two intersect O. Then with centre O and radius *o n*, describe the arc joining *nm*. This will give the line of the curve of the upper side of the handrail. Extend the radius to the depth of the handrail to obtain the line of the curve of the underside of the handrail.

The newel post may be finished with the cap detail which has been decided upon at a height suitable to give satisfactory proportions.

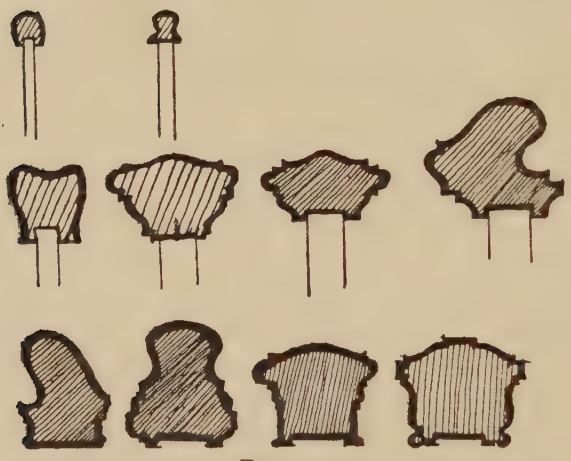


FIG. 202.

Together with this form of handrail usually goes a curved outer string as follows. The lines of the bottoms of the two strings, if produced, would cut the newel at different heights, which would look unsightly, consequently an easement is effected as follows. With centre O being the point at which the line of the upper string would cut the newel if produced and radius O1, describe an arc, calling the point at which it cuts the newel 2. Divide these two distances O1 and O2 into equal divisions. Intercross lines from one to the other, and their points of intersection will give the curve of the easement.

HANDRAILING

The name HANDRAIL is given to the support fitted at the side of a staircase for the hand of a person to rest upon when ascending or descending the stairs. Handrails are of various types and designs in section, from mop-stick to heavily moulded composite members.

They may be bracketed out on w.i. brackets 3′ 0″ apart with fanged ends built into the wall, as in an enclosed staircase, or supported on balusters rising from the outer string, or, as on landings, from a capping mould run along the floor boards.

The handrail should be fixed measured vertically from the nosing

FIG. 200.—ELIZABETHAN TYPE OF FLAT OPEN CARVED SPLAT BALUSTER, WITH JEWELLED AND STRAP-WORK RELIEF CARVING.

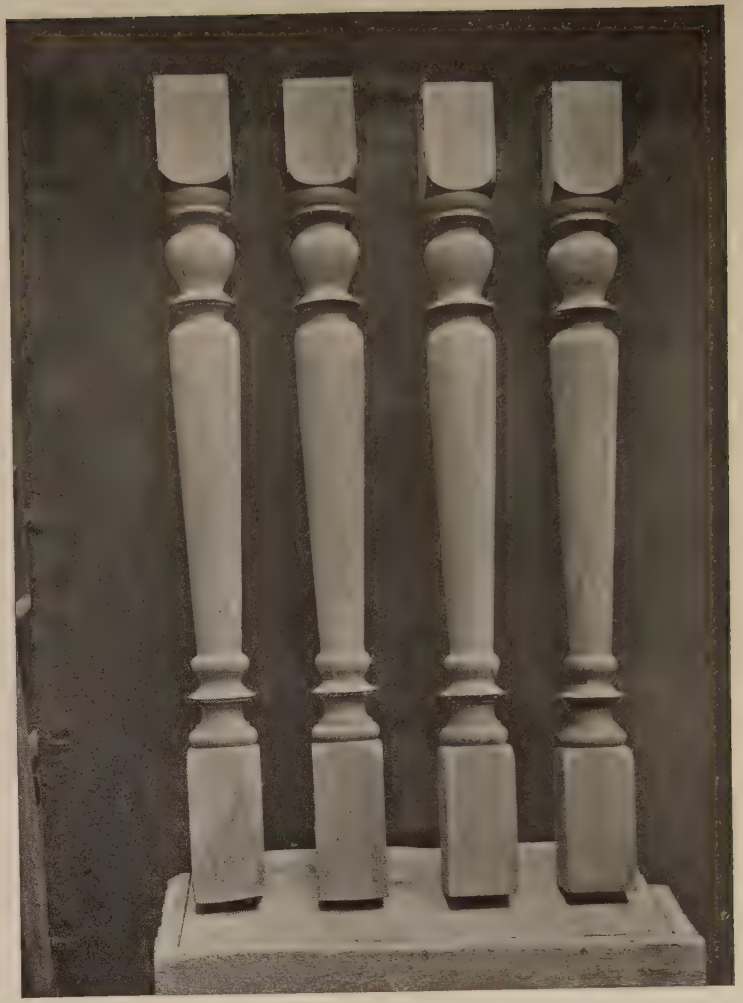


FIG. 201.—JACOBEAN TYPE OF BALUSTER.

of the tread at a height convenient for grasping with the hand. The height of the upper surface of the handrail from the tread should be from 2′ 7½″ to 2′ 8″, and to this there should be added at the landings the height of half a riser, the theory being that in ascending a person is in a less erect attitude than when walking along the level. However, in actual practice a height of 2′ 6″ from the nosing, and of from 3′ 0″ to 3′ 3″, will be found to give greater satisfaction.

The handrail may be fixed to the balusters by means of w.i. brackets screwed on, or by a continuous wrought-iron bar ¼″ thick, and as wide as the top of the balusters, the strip being screwed to both handrail and balusters.

The more customary method is that shown in Fig. 202, where it is grooved on its underside to receive the balusters which rise from the outer string into which they are housed or mortised and tenoned. The groove on the underside of the handrail is continuous in order that the balusters may be slid into position when the handrail is fixed, and the groove may be filled in between the balusters, if desired, when the balusters are in position.

Handrails should be run in continuous lengths where straight and possible, but when jointed may either be butted and fastened together with a w.i. plate screwed on underneath, or dowelled and splay cut.

Balusters are of varying designs, but with all the principles are the same, in that there should be no space greater than 4″ between them, and also that the face of a riser should line with the lower edge of a baluster and the intermediate span being filled with one or more balusters according to design. Where balusters rise from a cut and mitred string the ends of the risers are mitred against the vertical string or cut bracket, if a bracket is fixed, and the tread is mortised to receive their feet. The outer edge of the nosing is also mitred to receive a moulding planted on over the feet of the balusters and the cut bracket.

The method of fixing the handrail to the newel consists of a shoulder cut in the handrail pinned through the newel with oak pins.

The Science of Handrailing

Handrailing is the name given to the science and practice of forming and fitting handrails to stairs. When the handrail is not fitted into the newel post, as described above, it is usually carried over the top of the newel by means of a *ramp*. A ramp is a curve formed in the handrail to raise its line of direction in an upward direction, a *knee* being a curve in the opposite direction to continue the line of the rise. The combination of these two forms a double bend known as a *swan's-neck*.

In dog-leg or open newel stairs the lengths of handrail between the newels are generally straight, and where any curves do occur they are vertical and have their centre lines on plan coincident with the centre line of the handrail, as in the ramp and knee.

In a staircase consisting of two straight flights above and below a

landing having no newels, but a curved handrail, the method of laying it out is given in *Handrailing*, by George Collings, as follows :

From the termination of the straight posts of the handrail the centre lines of the handrail are continued in plan. Join the two centre points of the ends of the straight portions of handrail with the line 15, and halve it at the point *c*. Draw the arch of the circle 1, 3, 5, forming a semicircle, having *c* as centre.

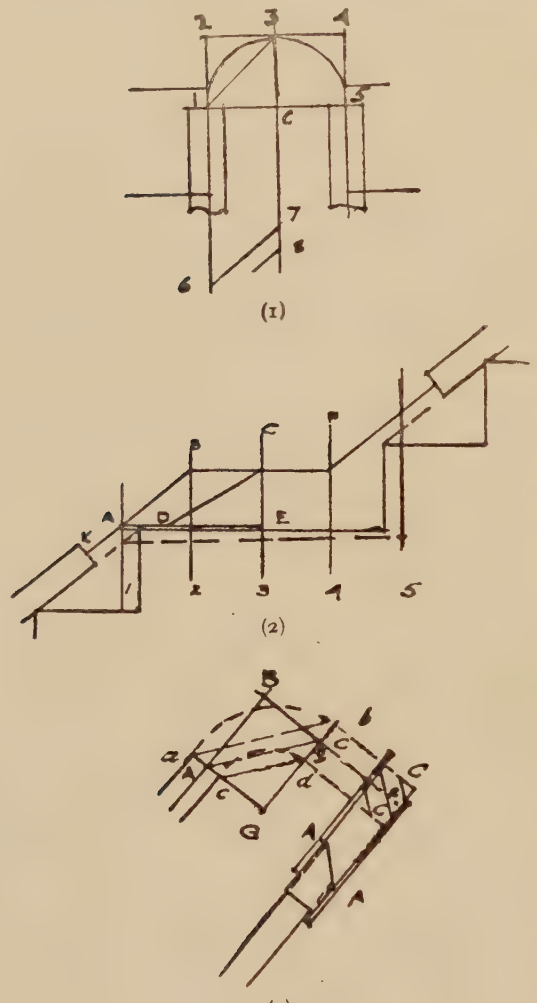


FIG. 203.

Draw the tangents 1, 2, 2, 4, 4, 5 and the diagonal 13.

To develop the centre line and tangents to obtain a stretch out of the above, draw the landing with the tread and riser above and below and erect perpendiculars to correspond with the points *a*, 1, 2, 3, 4 and 5, the distances from each being the same as in the plan. Next draw the line of the handrail resting on the nosings of the treads above and below and continue the centre line of the lower handrail till it cuts the vertical line 1 at A and the centre line of the upper handrail downwards until it cuts the line from 4 at F. Join BF with a horizontal line, calling the point C at which it cuts the vertical from the point 3. From A draw AE parallel to the landing and from E set off ED equal to the diagonal 1, 3. Join DC, which will give the diagonal of the mould.

To draw the mould the centre line of the handrail produced must equal AB in Fig. 2 (203), and from the point B draw BC at right angles, making BC equal BC in Fig. 2. Then join AC, which will equal DC in Fig 2. Produce the line AB until the distance AK is equal to the distance A in Fig. 2, and draw the end of the mould square to AB. Continue the square line to downward from A, and cut it with the square line from C, calling the point of their intersection G. This point will then be the centre of the elliptic curves of the mould. The line BC being level, the angle

ABC will be square, consequently the bottom end of the mould will be square and the same width as the rail. Draw the width of the rail parallel to AB. To find the bevel and width for the top end, take AB, Fig. 3, in compasses and with one foot at the point 6, Fig. 1, on the centre line of the rail draw the arc cutting the centre line of the well hole at 7. Join 6, 7, which gives the bevel, and a parallel to 6, 7, at the width of half the rail gives half the width of the mould. Repeat this distance on either side of C (Fig. 3), which will give the point to which the quarter-ellipses of the mould have to be drawn. Or, *a c* being the width of the rail, the lines *a*, *b*, *c*, *d*, being drawn parallel to AC will give *b*, *d*, its width at the centre of the wreath; and G*a*, G*b* will be the semi-axes of the ellipse of the rail, and G*c* and G*d* the semi-axis of the ellipse for the inside BC being level, AG and CG will be the directions of the diameters. G is the centre coinciding with the centre of the half circle in Fig. 1. Therefore from G to the inside and outside of the mould on each diameter will be half the shorter and half the longer axes respectively. If these distances be now marked off from the end of a thin straight-edge and carried round, keeping one of the points on each diameter, any number of points can be obtained through which the curves of the mould can be correctly drawn. Draw the lines AB and BC opposite to each other on both sides of the mould and square the springing across the inside edge. This will mark the termination of the straight part and the commencement of the circular, and will be made use of when the mould is applied to the plank. Both the wreaths being alike, there is no necessity to get out a separate mould for the upper one.

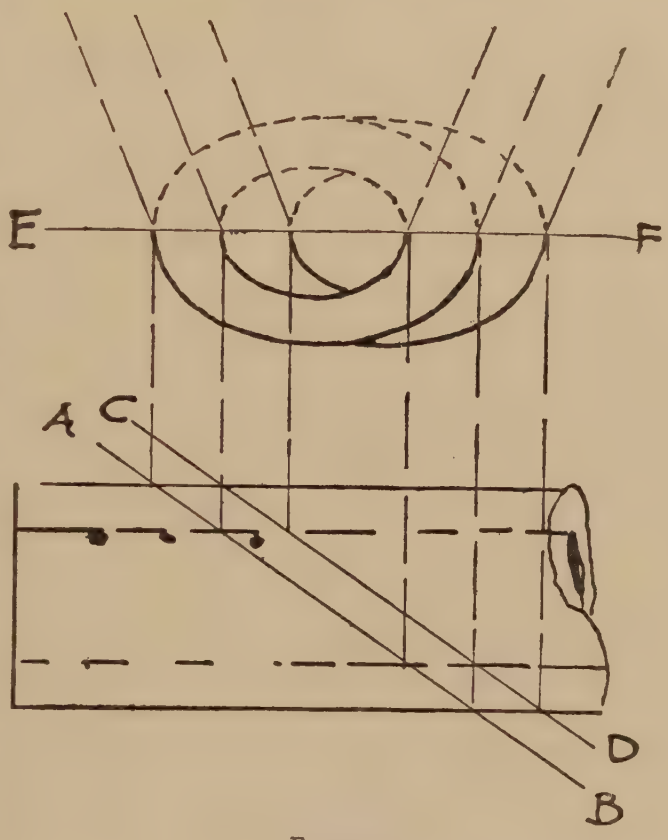


FIG. 204.

For fitting handrails to geometrical stairs the method known as

"Square cut and Tangent" is that most generally used. The term "square cut" applies to the cutting of the wreath pieces square with the face of the plank and also forming square or butt joints, whilst the term "tangent" refers to the method of setting out and determining the plane in which the section of the rail is contained, by means of lines drawn tangentially to the curve of the rail on plan. The simplest illustration which can be given of the curve required to form a wreath in a handrail is obtained by imagining a slice to be cut from a hollow cylinder, as shown in Fig. 204. The cylinder is cut diagonally by the lines AB and CD. These lines are parallel to each other, the distance between them being equal to the depth of the handrail in the square. The slice so cut is projected into elevation as shown, and cut through its axis by the line EF. By then eliminating half, which is shown dotted, and assuming the handrails joined to the remainder as shown, the curve of wreath is complete. It will, of course, be understood that this would not do for a handrail, as it is all across the grain, but it serves as a model to illustrate the principle, the object now being to obtain a rail of similar form, with the grain following the curve. The curve shown in Fig. 204 is for a half-turn wreath, and such must always be made in two pieces jointed in the middle in order to avoid cross-grain. Quarter-turn wreaths are worked from a single piece.

Fig. 207 shows the various drawings necessary for setting out a wreath over quarter-space winders on the tangent system. The first step is to draw an exact plan of the winders, with two or three flyers above and below as at (1) Fig. 207. On this plan the centre line of the rail is shown in a firm line, the width of the rail being indicated by dotted lines. The next step is to draw the "stretch-out" of the centre line of the rail, as shown at (2). To do this, draw the two lines A′A′ and C′C′ at a distance apart equal to the curved portion of the rail AC on plan, the curve being measured by taking a number of short steps with the dividers, this method being quite near enough for practical purposes. The points where the risers 11 and 12 occur are then measured off along the curved line AC on plan, and their position on the stretch-out is marked. The heights of the risers are then measured up either of the lines A′A′ or C′C′ and the stairs, 10, 11, 12 and 13 are drawn upon the stretch-out. The stairs, 8, 9, 14 and 15 are set out with the same going as is shown on plan. Now it is clear that the handrail should be the same height over each stair—that is to say, the handrail should be parallel with the nosing line. The nosing line is drawn, therefore, upon the stretch-out, and if it forms one continuous line, as in this case, it will be quite satisfactory. It sometimes occurs, especially when balanced winders are used, that the line connecting up the nosing line of the upper and lower straight portions of the handrail will fall above or below the nosing line of the winders and either arrangement is a source of great danger to users of the stairs. In such a case there are two methods of overcoming this difficulty. If the stairs have not already been constructed, they should

FIG. 205.—ELIZABETHAN TYPE OF OPEN SPLAT CARVED BALUSTER, POSTS AND HANDRAIL.

FIG. 206.—JACOBEAN TYPE OF TURNED BALUSTER, CARVED POSTS AND HANDRAIL.

be again set out on the stretch-out, so as to give a more satisfactory falling line, as the centre line of the rail over the winders is called. If the stairs have already been constructed, then the falling line of the wreath must be adjusted so as to be as nearly as possible coincident with the nosing line of the winders, and where it joins the straight rails a slight curve or "easing" is employed, so that the slight difference in height of the rail above the stairs is less perceptible to those who have to use the stairs. The more gradual the easing, of course, the less perceptible is the variation in height, but the thicker will be the stuff from which the wreath piece is cut.

The curved part of the handrail is now enclosed in a triangular prism ABC on plan, with the planes BA and BC tangential to the curve at the springings A and C, and a development, or stretch-out, is made of these tangent planes, as shown at (3), Fig. 207. To do this the prism is stretched out, the lines A″A″, B″B″ and C″C″ corresponding with the edges A, B and C on plan. The risers are then projected upon this development from the stretch-out of the central line of rail. The treads are measured off the plan, and, in the case of stairs 10, 11 and 12, the treads are measured off along the tangent planes AB and BC on plan. The centre lines of the upper and lower straights are drawn in their position above the nosing lines, the upper line being produced to cut the line B″B″ at *b*. The point *a′* on the stretch-out is then projected on to the point *a* in the line A″A″ on the development of the tangents, and the points *b* and *a* are joined and produced to meet the centre line of the lower straight rail. The distance FG is measured off along the level line through *a*, equal to the distance AC on plan, and *c*G is joined. It should be noted that, if the drawing is correct, the point on the development of the tangents will be level with the point *c′* on the stretch-out of the central line of the rail. The lines *ab*, *bc* and *c*G are the true lengths of the sides of the section of the prism ABC, which contains the central line of the curved portion of the rail. To obtain the face mould, set down the line *a″c″* equal to G*c* as shown at (4), and with centre *a″* and radius *ab* describe an arc and with centre *c″* and radius *cb* describe another arc, cutting the former arc at *b″*. Join *a″b″* and *c″b″*; *a″b″c″* is the true shape of the section of the prism containing the centre line of the rail. From *a″* and *c″* draw the lines *a″*O and *c″*O respectively, parallel to *b″c″* and *a″b″*. Then O is the centre of the elliptical curves bounding the face mould.

To obtain the width of the mould at the end *a″* produce the tangent *a″b″* and from *c″* draw *c″*H perpendicular to it. Take the distance *c″*H with a pair of compasses, and from any point L in the line B″B″ (3) and with radius *c″*H strike an arc, cutting the line A″A″ in M. Join LM, and with any point in LM as centre describe a circle with its diameter equal to the width of the rail on plan. Draw lines tangentially to this circle and parallel to LM, cutting the line A″A″ at N and P. Then, with NM or NP as radius, describe a circle with its centre on *b″a″*, produced

as shown at (4) Fig. 207, and draw lines tangentially to this circle and parallel to $a''b''$, cutting the line Oa'' at Q and R. Then QR is the width of the mould on the springing line.

Similar construction is shown for finding the points S and T at the other end of the face mould. If lines drawn through Q and R parallel

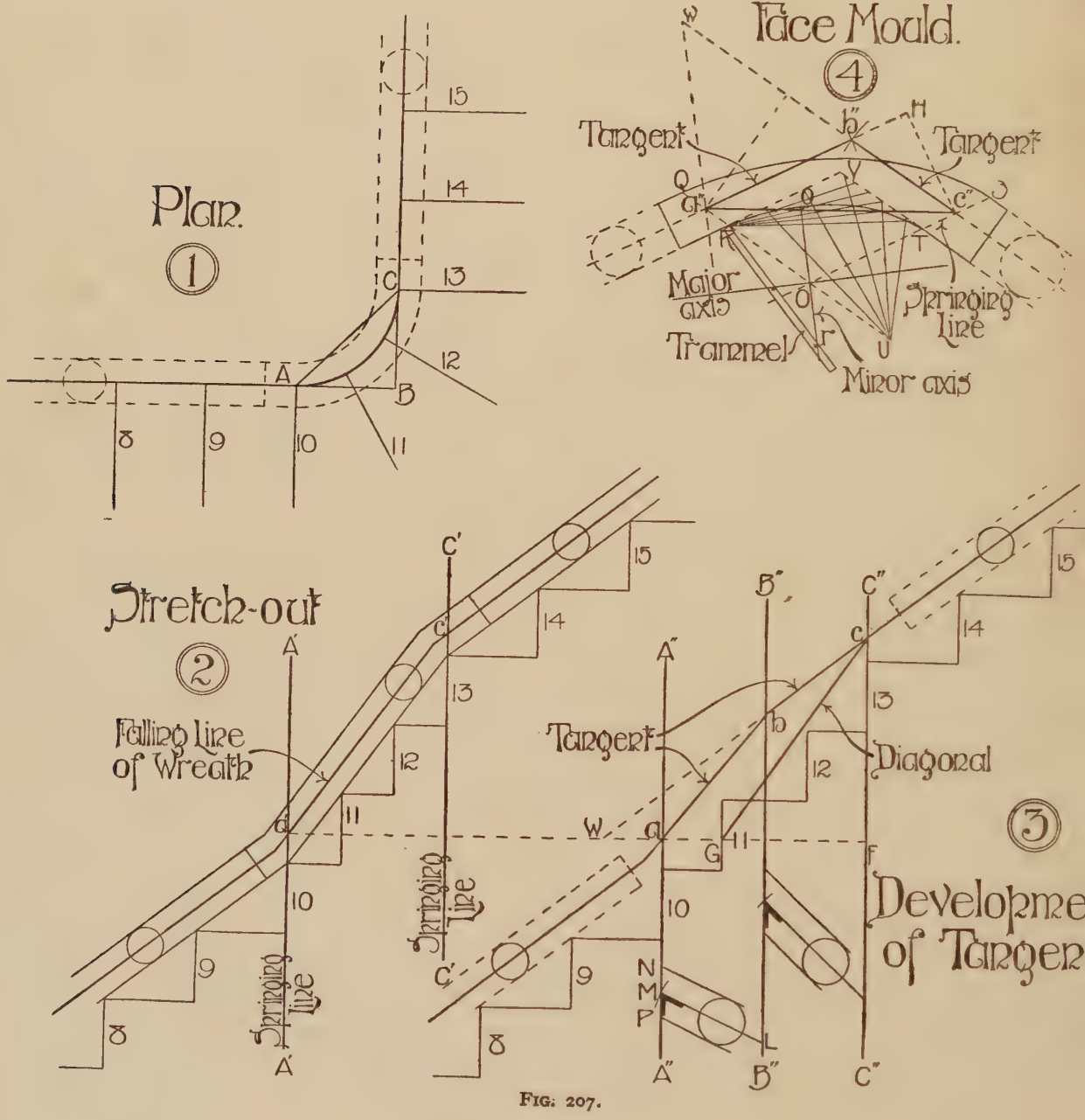


FIG. 207.

to *a″c″* pass through the points S and T respectively the accuracy of the setting out will be proved. The points, Q,R,S and T are the points from which the elliptical curves are struck. To strike the curve RT produce RO to U, making OU equal to RO, and draw RV and TV respectively parallel to OT and OR. Divide OT into any convenient number of equal parts. From R draw lines to the divisions of TV, and from U draw lines through the divisions of OT; the points where these lines cut the first set of lines mark points on the ellipse as shown. The upper curve is set out in a similar manner.

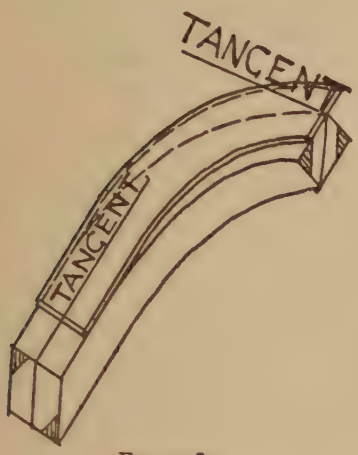


Fig. 208.

These curves may be checked by finding the axes of the ellipse of which they form part, and trammelling the curves. This is done in the following manner: Produce *cb* (3) to meet the level line through *a* at *w*. Produce *c″b″* (4) to *w*, making *b″w* equal to *bw* on the development of the tangents. Join *wa″*, and through O draw O*o* parallel to *a″w*; then O*o* is half the minor axis. Mark off the length O*o* from the unlettered marked point to its end R on a slip of wood called a "trammel" and place this in the position shown, its length R*r* being equal to the length of half the major axis by placing the trammel in various positions with the two marked points on the axes, the end of the trammel with marked points on the curve of the required ellipse.

The joints are then drawn square with the tangents and at the same distance from *a″* and *c″* as they are from the corresponding points on the development of the tangent. The bevels for setting the ends of the wreath piece are found when finding the width of the end of the face mould. These are shown blacked in at (3).

Having now obtained our face mould and bevels, theory ends and practice begins. The method of using the mould is shown in Fig. 208, the bevels being marked across the end of wreath piece, the shaded portions are worked off, the other angles being "squared" from these. When this has been done the wreath is complete up to the point known as "in the square." Each end should then in turn be jointed temporarily to the straight rail, and the moulding worked a little way on. It is then taken off and the mould completed.

Drawing Ellipses and Scroll

(See Figs. 209, 210, 211, on page 133.)

Having decided upon the width desired for the scroll, divide a line of that length into eight parts, starting from the centre line of the straight handrail at *a* in a vertical direction downwards, marking the divisions with the fingers 1 to 8 respectively. Next divide the distance between

points 4 and 5 in halves, marking the point *o*. From *o* as centre and *oa* as radius describe the quadrant of a circle, calling the point at which the quadrant cuts a line drawn from *o* at right angles to *o*, *c*. From the same centre draw two additional arcs on either side of the arc *ac*, each being the distance from *a* of half the handrail width, and calling the points where they cut *oc*, *w* and *n* respectively. From the point 8 as centre and 8, 7 as radius, describe an arc, calling the point at which it cuts a line at right angles to 8*a*, 9. Draw a line from 9 to *d* parallel to 8*a*, calling the point *d* at which it cuts *oc*. Join 9 to *a*. With *d* as centre and *dn* as radius describe the quadrant from *n* to *r*, calling the point at which it cuts 9*d* produced, *r*. In the same manner complete the inner quadrant from *w* to *s*, calling the point at which it cuts *d*9, *s*.

Next, from *c* draw a line at right angles to 9*a* and through its point of intersection of *a*9 draw a line from *o* to *e*, calling the point at which it cuts 9*d*, *e*. Then, with *e* as centre and *er* as radius, complete the next quadrant from *r* to *t*, calling the point at which the quadrant cuts a line drawn from a point half-way between 5 and 6 on the line *a*8, *t*.

For the fourth centre draw line from *d*, passing through the intersection of *a*9 and *oe*, and from *e* draw a line parallel to *oc*, calling the point at which it cuts *df*, *f*. Then, with *f* as centre and *ft* as radius, describe the quadrant from *to* to *x*, calling the point at which it cuts *a*9, *x*.

From *f* erect a line parallel to *o*8, calling the point *t* at which it cuts *oe*, *g*, and from *g* as centre and radius *gx* describe the quadrant *x* to *y*, calling the point at which it cuts the line drawn from *c* at right angles to *a*9, *y*.

From *g* draw a line parallel to *oc*, calling the point at which it cuts 9*d*, *h*. Then, from *h* as centre and *hy* as radius complete the scroll until it meets the inner face of the second arc at *z*.

For use as a template the scroll should be placed over the drawing, showing the straight handrail and the risers of the steps to that over which the scroll springs. In the drawing this is taken as riser No. 4. The centre line of the scroll from *a* to *c* then coincides with the centre line of the outer string; upon this centre line the points of intersection of the risers may be marked at 4, 3 and 2 respectively, and their sweeps completed.

Along a perpendicular line erected from the point marked 4 measure of distances equal to the height of the four risers contained in the scroll curve, marking them 1, 2, 3 and 4′. At 4′ place the pitch board and draw the pitch of the steps from 4′ to *b*′; from *b*′ draw *b*′*c*′ horizontal, making it equal in length to *bc* on plan. The line 4′*b*′ is the elevation of the tangent 4*b* and the line *b*′*c*′ is the elevation of the tangent *bc*.

The Face Mould for the Wreath

(See Fig. 211.)

To lay out the face mould for the wreath make *a* 4′*b*′ equal to *a* 4′*b*′ in Fig. 209, and at right angles to it from *b*′ draw the line *b*′*c*′, equal to *b*′*c*′ in Fig. 209. Complete the square 4′ *b*′*c*′*o* of which the line *b*′*c*′

represents the level tangent $b'c'$ in Fig. 209, and the line $4'b'$ similarly represents the raking tangent $4'b'$, and the lines $c'o$ and $o4$ are the major and minor axes respectively.

Next place the pitch board with its upper angle at the centre of the underside of the handrail and project down on to it a vertical line from its outer face, calling the point at which it cuts the pitch n. On either side of $4'$ mark off the half width of the handrail at points i and x, and on either side of c' mark off the distance mn on the pitch board.

With the dividers spaced at the distance on and with centre at i on the minor axis, describe the arc m to ll, calling the points where it cuts the major axis produced ll. At these points insert pins and round them stretch a looped string extending to i. From the point i with a pencil engaged in the looped string describe the ellipse i to n. For the inside curve proceed similarly, placing one leg of the dividers on the point x on the minor axis, with radius om on the major axis, and draw the arc 2 to 2, calling the points at which it cuts the major axis 2,2. From these points and x describe the ellipse with the aid of the looped string and pencil, from x to m.

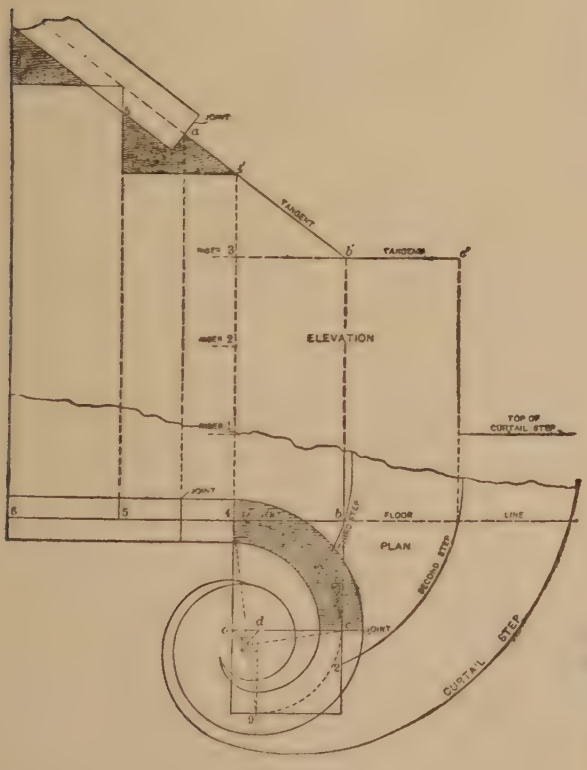


FIG. 209.

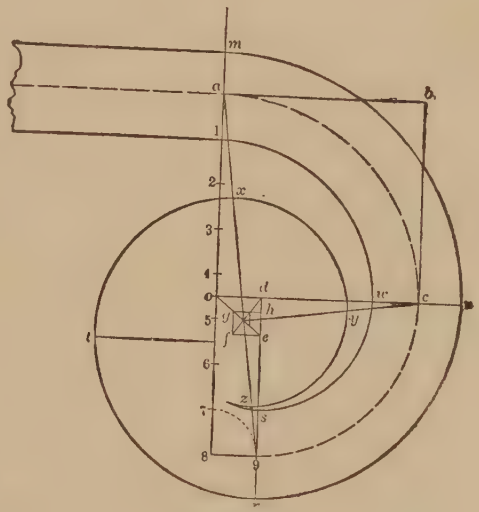


FIG. 210.

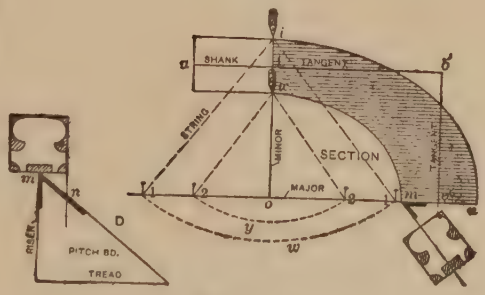


FIG. 211.

CHAPTER VII

PARTITIONS

Definitions—Classes of Partitions: Single Upright Stud Partitions; Framed and Quartered; Trussed; Sills—Interties—Posts—Braces—Joints—Partitions in Framed Buildings—Corners—Openings—Prevention of Sound—Sliding Doors—Loads—Mill Construction—Steel and Wood—Weights and Scantlings.

A PARTITION is a dividing wall between the rooms on the same floor of a building. In carpentry the framework of the partition is of wood; and its covering of lath and plaster. Wooden partitions are necessary only where solid bearing on a brick wall underneath cannot be obtained. Where such a bearing is to be obtained, the divisions will be built of brick and their construction, except in so far as the fixing of door frames, plates, fixing blocks, etc., will not concern the carpenter. In modern construction, however, fireproof methods and materials are becoming more customary, and to this end the brick nogged partition is to be more frequently met with. This consists of upright wooden studs having the spaces between them filled in with bricks either placed in the usual manner or on edge. Another name for the partition is *stoothing*, but this term is not met with in the south.

Though the general practice is to build ordinary partitions directly upon the floors, this is bad construction, because if the floor sags the partition must go with it, causing the plaster to crack. The weight of the partition also causes the floor to sag, with resultant cracking of the ceilings underneath.

In better construction, the partition will be hung from the floor above, or from the roof, where they must be dependent. But the best construction of all will be that in which the partition is built in the form of a truss from wall to wall, and of sufficient strength to carry not only its own weight, but if necessary that of the floors above and below.

CLASSES OF PARTITIONS

Partitions are of three kinds, as follows:

1. Simple upright studs.
2. Framed or quartered.
3. Trussed: (*a*) Self-supporting; (*b*) Partitions supporting floors.

SIMPLE UPRIGHT STUD PARTITIONS, Fig. 213, are also termed common partitions, and consist of a head 4″ by 3″ or 4″ by 4″, upright studs 4″ by 2″, spaced at intervals of 12″ to 18″ from centre to centre,

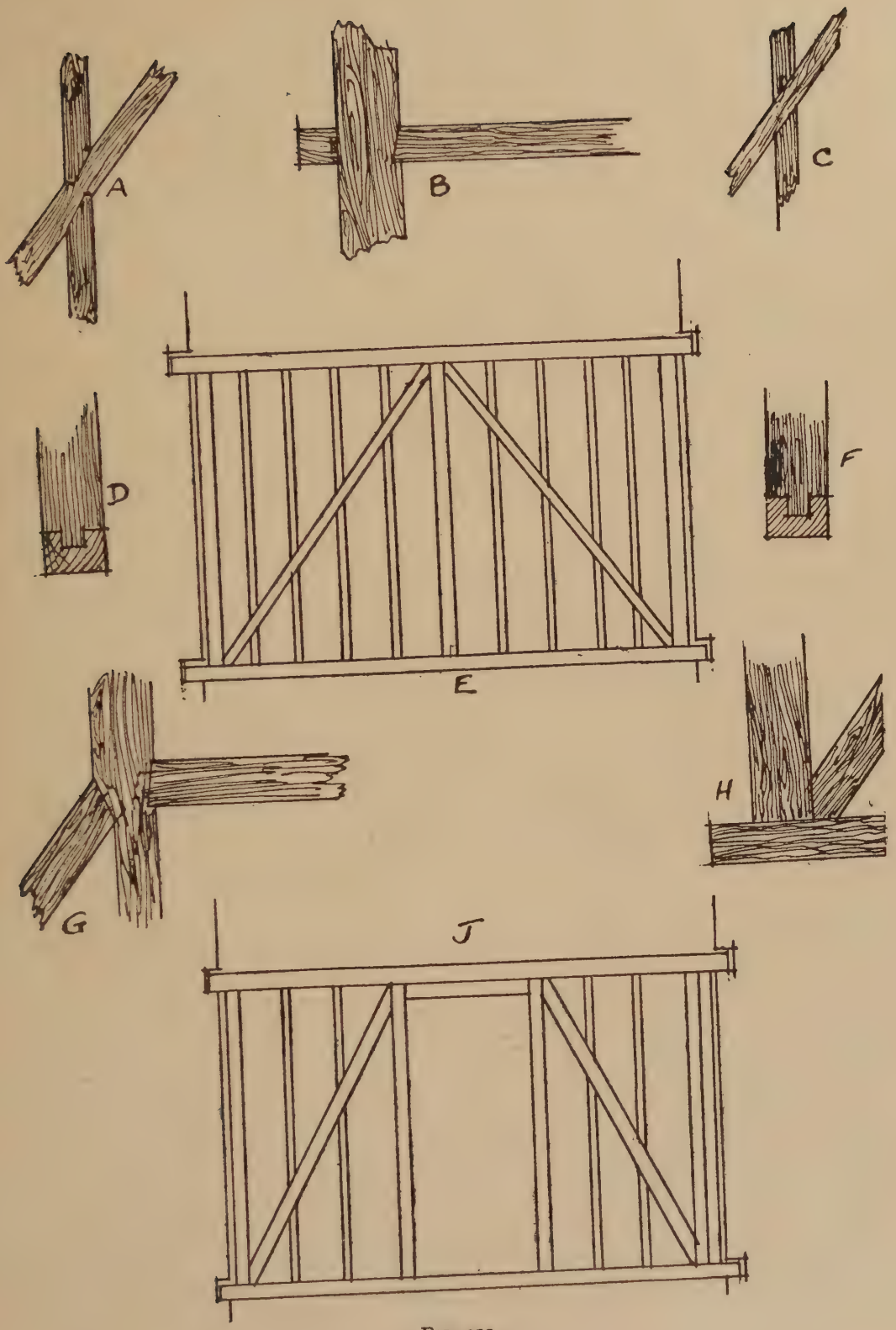
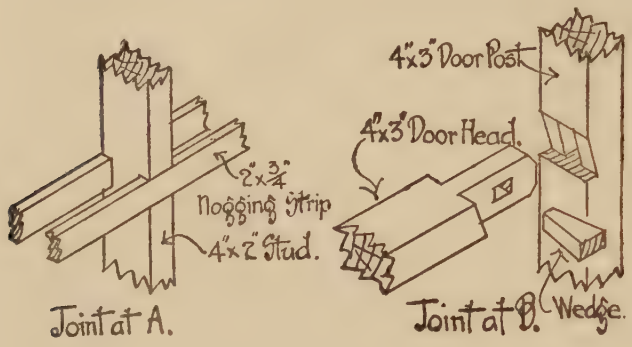


Fig. 212.

and *nogging* pieces 4″ by 2″ cut to fit tightly between them horizontally at intervals of from 3′ 0″ to 4′ 0″. Nogging strips 2″ by $\frac{3}{4}$″ may be let into and spiked to the studs in place of nogging pieces. Door studs will either be doubled or of 4″ by 3″ or 4″ by 4″, to give additional strength and to provide fixing for door frames. The sill will be cut where door openings occur. Heads to door openings should also be doubled, or of 4″ by 3″ or 4″ by 4″, according to the width.



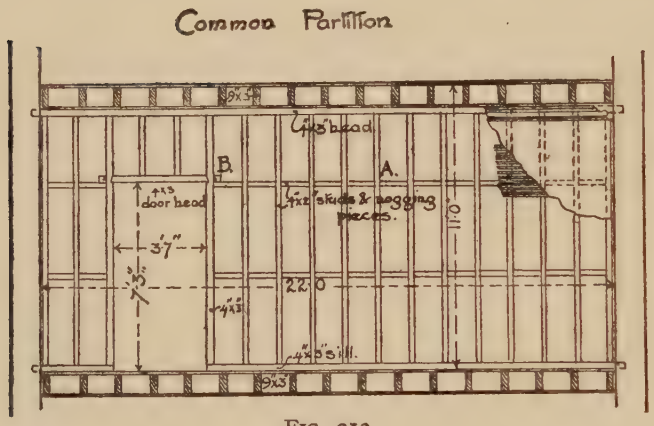


Fig. 213.

Where the partition runs the same way as the floor joists, the joists immediately under it should be doubled. And where an under floor is employed, as in America, sills are often laid on the under floor ; though this practice is not recommended, owing to the trouble which arises should it be necessary to remove the flooring for any purpose. There should be a clearance above the heads of these partitions to prevent the floor above bearing upon the partition in case of sagging.

Spacing of Studs.—A simple rule in this matter is that where the stories exceed 9′ 6″ in height the spacing should not exceed 12″.

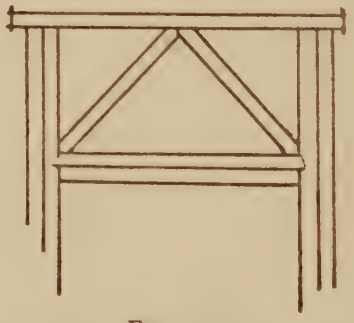


Fig. 214.

Framed or Quartered Partitions.—These consist, as before, of heads and sills 4″ by 3″ or 4″ by 4″, studs 4″ by 2″, nogging or stemming pieces of 3″ by 2″, but in addition there are introduced braces, 4″ by 3″, which run diagonally from the walls at the base to a point in the centre of the head, where they meet. The outer studs are doubled or 4″

by 4″, single studs and a post, 4″ by 4″, may be introduced from sill to head at the centre.

Where doorways occur, the partition is framed in the manner shown in Fig. 214, it being remembered that door studs and heads should be doubled.

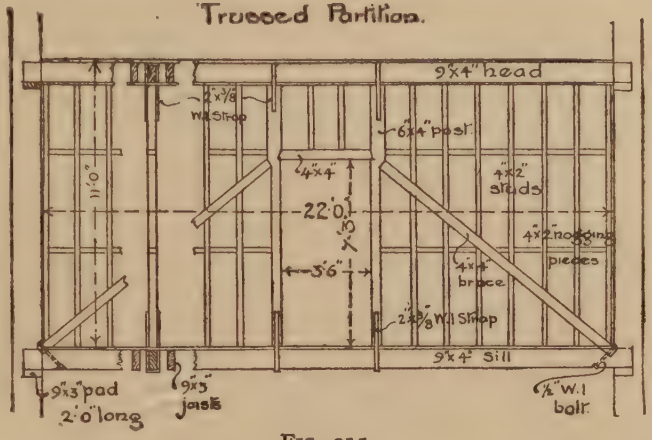


Fig. 215.

Trussed Partitions.—(*a*) *Self-supporting.* Where it is desirable to remove the weight of the partition from the floor below, *self-supporting* partitions are introduced. In these the timbers are so disposed that the pressure due to weight is diverted to the walls abutting the partition. The principles applicable are those of the king post and queen post trusses, already described under "Roofs." The sill, where uncut, forms

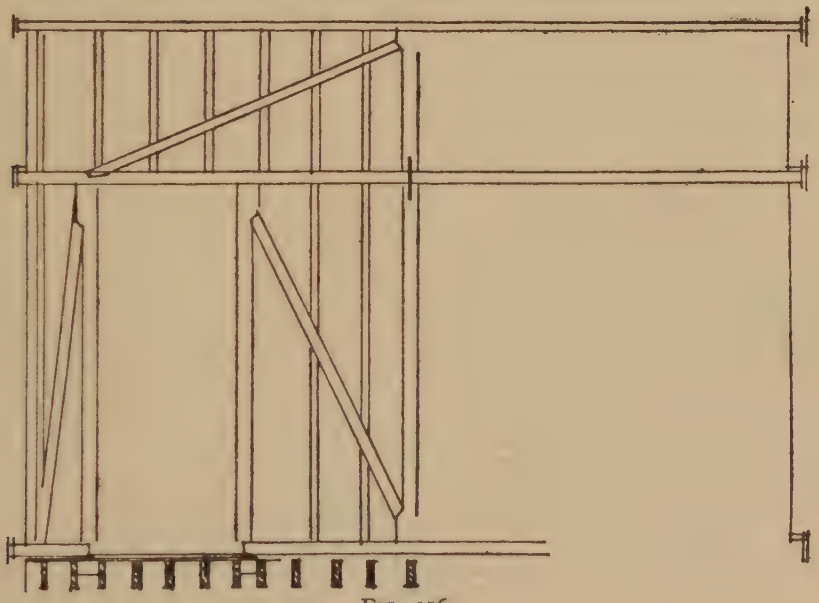


Fig. 216.

the tie, diagonal struts take the place of the principals, and a central strengthened stud becomes the king post. However, should there be openings desired for a door or doors, the studs at the sides of the openings are strengthened and the truss becomes a queen truss.

When more than one opening necessitates the cutting of the sill to the extent that the tie is destroyed, a king post truss, with a tie forming the heads of the door openings, is introduced in the manner shown in Fig. 216.

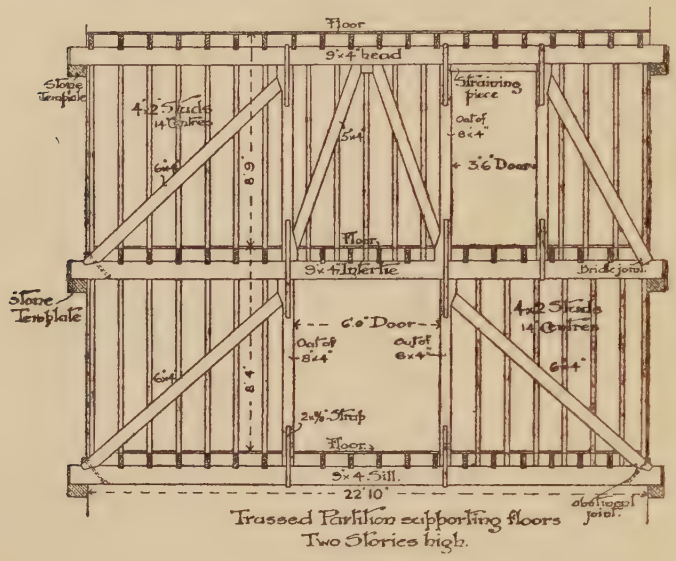


Fig. 217.

(*b*) *Trussed Partitions Supporting Floors.*—The framing here is the same as last described, with the difference that the timbers must be of larger dimensions and the braces more numerous. Horizontal timbers called *interties* are introduced as described in the last, having the effect of directing the loads past the door openings and distributing them upon the abutting walls.

Heads.—The head acts as a straining beam for the braces at the same time as it forms a fixing for the posts and studs. As may be seen in Fig. 217, trussed partitions supporting floors are frequently built of one structure two stories in height, and the floor joists are then notched or cogged over the heads and interties. The ends of the heads, interties and sills should be built into the walls with properly ventilated spaces around them and resting on stone templates.

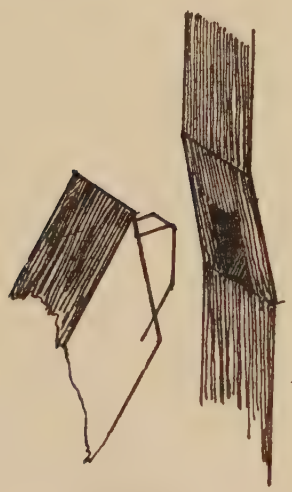


Fig. 218.

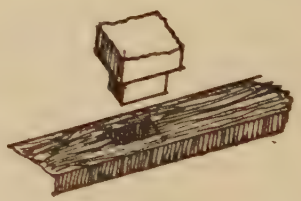


Fig. 219.

Sills.—The sills form the bottom tie, and give fixing for the diagonal braces as well as the upright studs. They also perform the services of a binder to the lower floor joists.

Interties.—As explained, these enable the upper portion to be formed into an additional truss, and the intertie itself also acts in the same manner as the sill in becoming a binder for the intermediate floor joists.

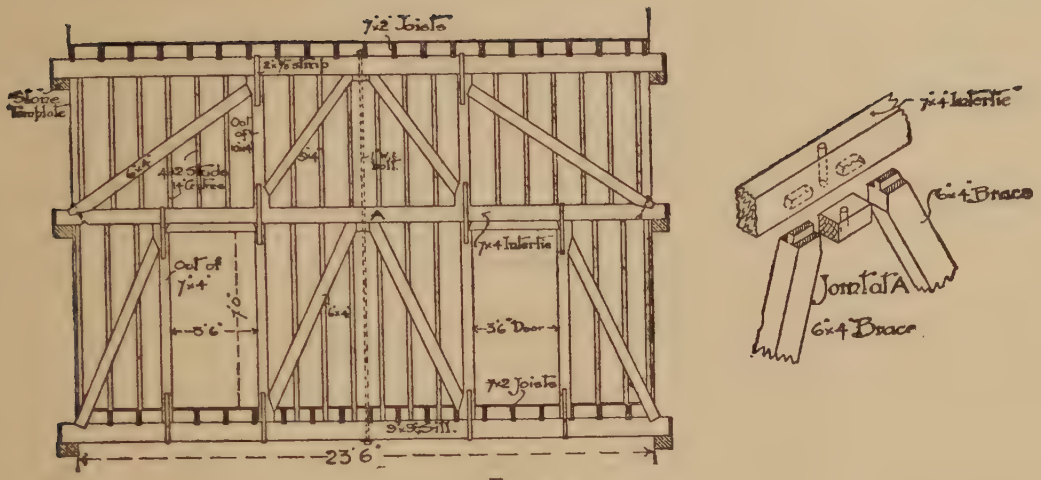


FIG. 220.

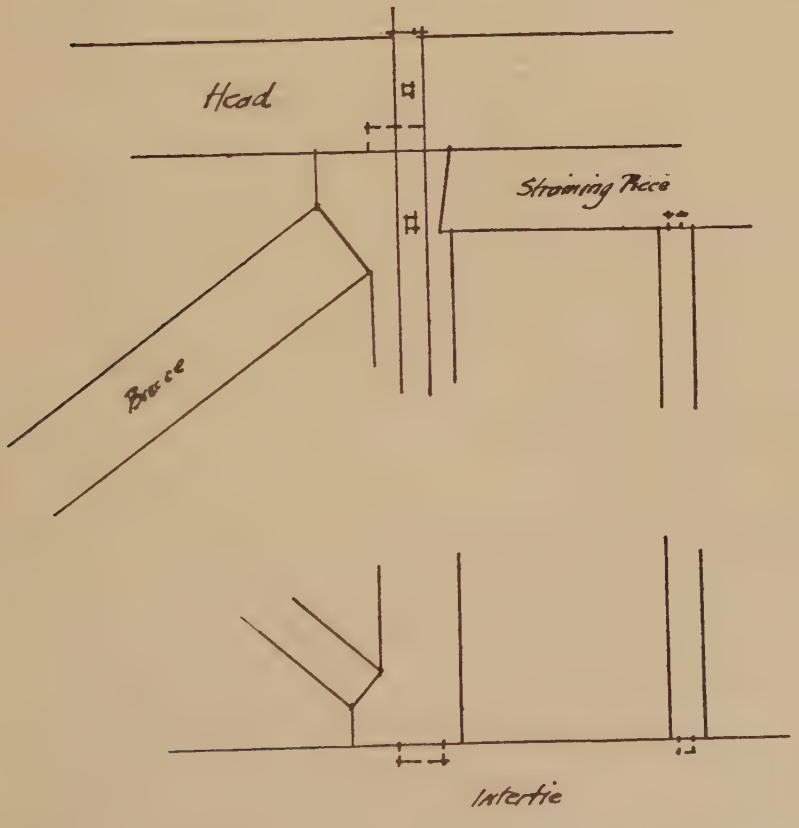


FIG. 221.

Posts.—Where openings occur, and intermediately where there are no openings, posts are introduced running in one length from head to intertie, and again from intertie to sill. As will be seen from Fig. 222, shoulders are formed on the heads and feet of the posts in the same way as described under roofs for king and queen posts.

Braces.—To transmit the load from the centre of the partition to the walls, braces are introduced diagonally. They should be connected to the heads, interties and sills by means of bridle joints as shown. They will be found most effective when built at an angle of 45°.

Studs.—These are run vertically between the heads, interties and sills, and are stub-tenoned thereto. Where intersected by braces, they are cut splayed.

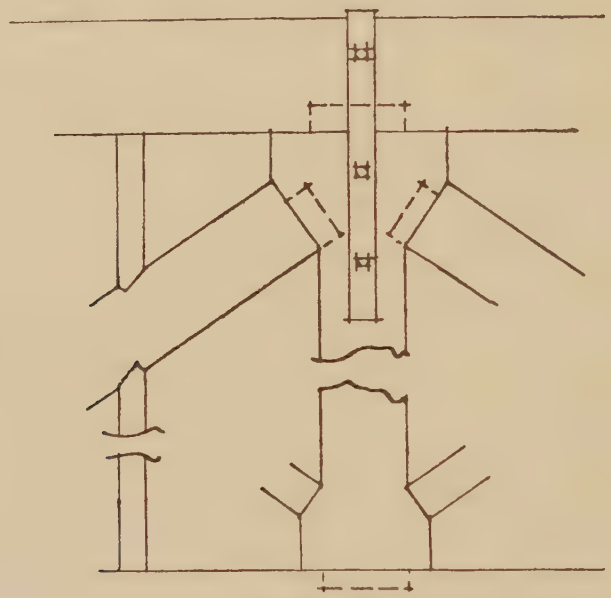


Fig. 222.

Scantlings of Timbers.—The following list gives approximately the sizes of timbers used in partitions, spanning distances up to 20′ 0″:

Heads	4″ by 7″ to 4″ by 9″
Door heads	4″ by 3″ to 4″ by 4″
Interties	4″ by 7″ to 4″ by 9″
Sills	4″ by 7″ to 4″ by 9″
Posts	4″ by 4″ to 4″ by 6″
Braces	4″ by 4″ to 4″ by 9″
Studs	4″ by 2″

Braces should be increased in sizes in accordance with their length.

In proportioning the sizes of any timbers in a truss, only approximate figures can be given. For greater accuracy the stresses should be

calculated ; but in all cases it is well to remember that the thicknesses should be kept the same in order that a flush face may be maintained on both sides of the partition for plastering to.

Joints Used in Partitions

Mortise and Tenon is used between the head and sills and the posts, the tenon being, as in other cases, one-third of the thickness of the timber on which it is cut, leaving two-thirds bearing, called shoulders, to rest upon the cheeks on either side of the mortise.

Stub-tenon is the name given to the joint used between studs and sill or head, the tenon serving the purpose of keeping the stud in position, and penetrating the head or sill about 1″.

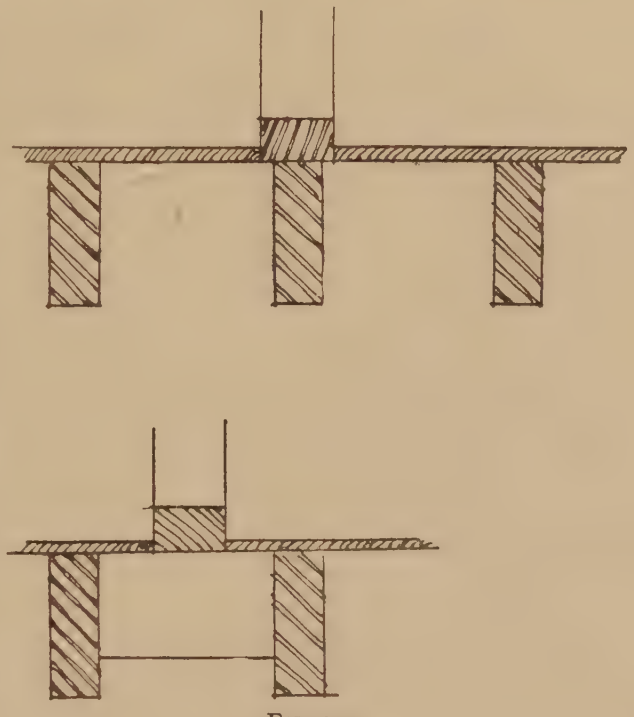


Fig. 223.

Between Studs and Braces a joint, as shown in Fig. 212 (A) being a shouldered diagonal halving, is best employed, but for cheapness a plain diagonal halving of the type shown in Fig. 212 (C) is more often used.

Brace Post and Sill. — The joint used here in its simplest form is that shown in Fig. 212 (D), where the brace is double splayed. But where the post is a door post, shoulders of the type shown in Fig. 212 (G) are employed, the brace and heads being tenoned into the post whilst the post is thickened out to take the cutting.

Door Head and Post.—Where the brace does not spring from the post, a joint similar to the *tusk tenon* on its side with a splayed shoulder as shown in Fig. 213 is used.

Joints in Trussed Partitions.—These, as may be seen from Fig. 220, are similar to those used in king and queen post roofs.

Partitions not Over Joists.—Where the partition does not come over a floor joist, bearers are cut in, as shown in Fig. 223, every 4′ 0″ apart.

Partitions in Frame Buildings

In frame buildings, or where one wood partition comes over another, the studding of the upper partition should rest on the head of the partition below.

In frame buildings of a cheaper nature, as shown in Fig. 226, the floor joists rest upon the head of the partition below and over these the under flooring is run. On this the 2″ by 4″ sill of the partition above is laid. If, however, the floor joists are supported by hangers to a beam, the studs of the partition above may be run from the same beam as a sill.

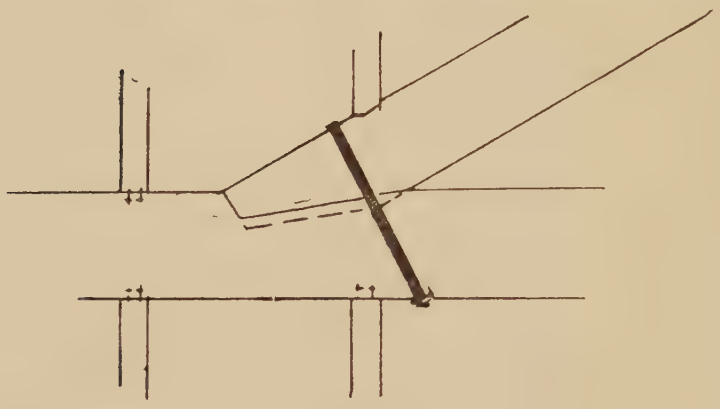


Fig. 224.

When the partition runs the same way as the joists, double joists may be inserted, but the method is not recommended for the following reasons. If the beam is not less than 3″ wider than the partition, it does not give a nailing for the ends of the upper floor boards ; and if there are any pipes to run in the partition, the beam must be cut away through most of its thickness to let them by. So two joists, spaced a short distance apart and bridged as described, is a better method. This gives a good nailing for the floor boards, and allows of plenty of space for the passage of pipes.

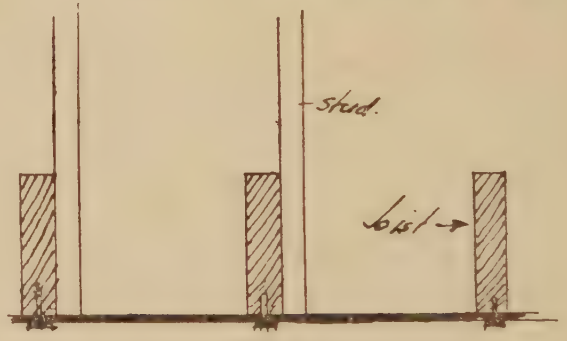


Fig. 225.

Corners.—The corners in intersecting partitions should be as at *a* or *b* in Fig. 227, whereby nailing for lathing is facilitated. Where the wooden partition abuts on to a brick wall, additional stability will be gained by bolting the last stud or post once or twice in its height to the wall.

Openings.—The spaces over all openings in partitions and outside walls where built of wood should be trussed as shown in Fig. 229.

Prevention of Sound.—Where for any reason it is desired to

prevent sound from penetrating from one room to another through the partitions, the interstices of the partition may be packed with sound deadening material, such as mineral wool, sawdust or other. But the objection to this practice is that the studs still maintain the connection from one plaster face to the other, by which sound is still conducted.

A better way is to construct a partition known as a *staggered partition*, in which the studs are placed in two rows, those of one side coming halfway between those of the other side. By this means the two sets of studs are kept separate from each other, and the two sides of the partition do not connect in any way. Sound-deadening felt may be tacked on the insides of the studs as an additional preventive.

Sliding Door Partitions. —A practice which has been somewhat discontinued of recent years, of providing single or double sliding doors between rooms, may be conveniently revived in days of the growing popularity of dancing. The partitions for the accommodation of sliding doors must be built double. In order that the partitions may not be unduly wide and so occupy too much of the floor space, the studs should be placed flatways, this resulting in a partition of 6″ in width, consisting of two rows of 2″ studs and two thicknesses of $\frac{7}{8}$″ for lath and plaster; the remainder being the internal space for the

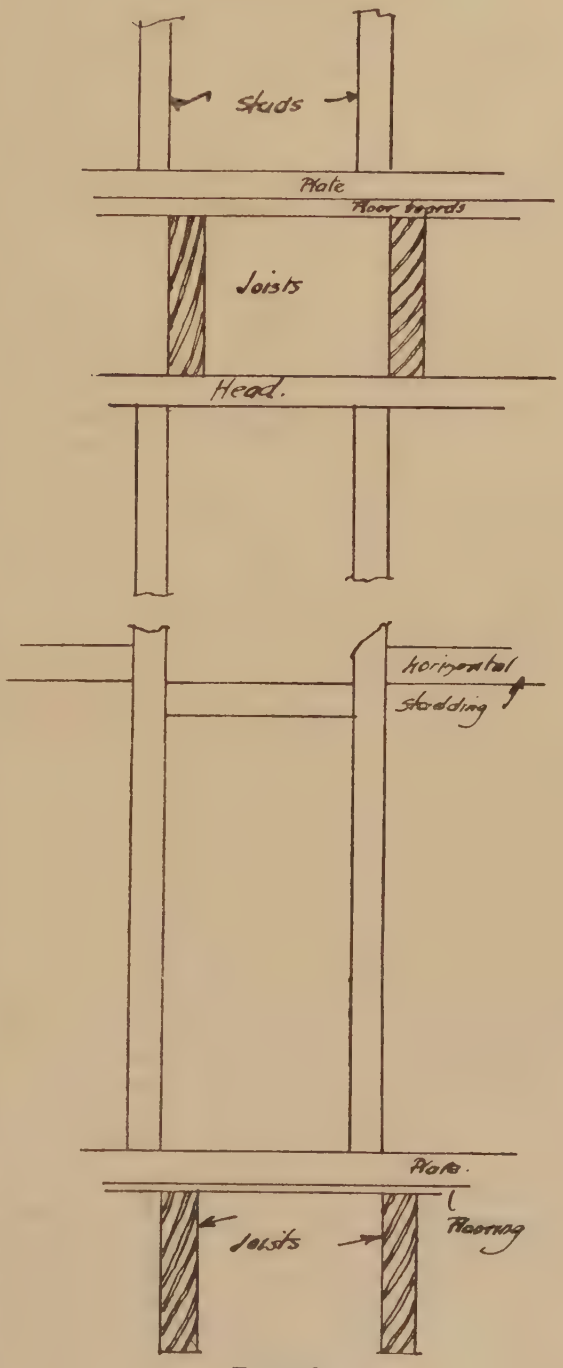


Fig. 226.

accommodation of the sliding door. But 2″ by 4″ studs of over 9′ 6″ in height, placed flatways, will not give sufficient stiffness. If the partition is a bearing partition, one side may be made thicker than the other to carry the load imposed. The space over the opening will, of course, as has been said, be trussed. The inside or sliding space may in better-class work be sheeted with thin match-boarding to prevent the plaster from falling on the tracks on which the sliding doors operate. To enable this sheeting to be fixed, it will be obvious that the partition must be framed and sheeted and raised into position and then fixed.

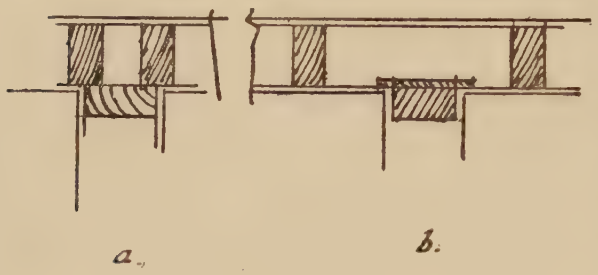


Fig. 227.

Loads on Partitions

As has been explained, the purpose of a trussed partition is to relieve the floors from the weight of the partition and transfer it to the walls; but where this is impossible, and if the weight of the partitions is not within the loading figure for the floor, the partition may be slung by steel suspension rods from a beam or rolled-steel joist above, as is shown in Fig. 228. The suspension rods are fitted with bolts and washers, those on either side of the steel joist being wedge-shaped. The rods should be well distributed in the length of the partition and calculated to carry the weight imposed.

Fig. 228.

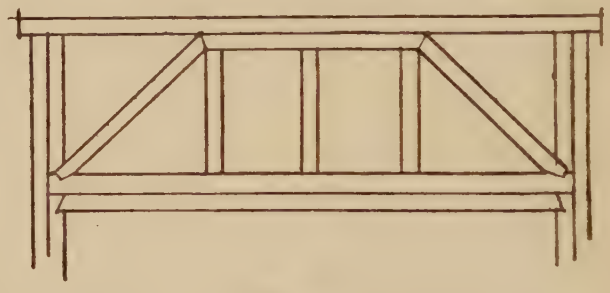


Fig. 229.

Partitions in Mill Construction

Solid partitions in timber built without air spaces are used in mill construction. They are built up of 2″ planks, and covered with sheeting lath.

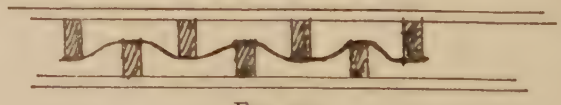


Fig. 230.

Steel and Wood.—The only sure provision against cracks in the plaster work of partitions not resting on solid walls

is to support them on steel beams. The shrinkage in the joints where the partitions run the same way as the joists, will occasion settlement with consequent cracks. Where the partition runs at right angles to the floor joists, the joists should be cut into and the partition built upon the top flange of the joist.

When the partition cannot be supported in this manner, either on account of the cost or the necessity of running pipes in the partition, or for any other reason, the effect of shrinkage may be overcome by screwing 4″ wide by ⅜″ thick iron plates to the bottoms of the joists for the studs to rest upon.

Weights and Scantlings Used in Calculating for Partitions

	lbs. per square
Partitioning . . .	from 1,480 to 2,000
Single joisted floor without counter flooring . .	,, 1,260 ,, 2,000
Framed floor without counter flooring . . .	,, 2,500 ,, 4,000

Scantlings of Principal Timbers in Partitions

4″ by 3″	for bearing not over	20′ 0″
5″ by 3½″	,, ,,	30′ 0″
6″ by 4″	,, ,,	40′ 0″

CHAPTER VIII

THE STEEL SQUARE AND POWER PLANT

By Harold Ryder

Human Machinery of the Past—Power Plant of the Present—Mind from the Men and Power from the Mains—The Steel Square and its Tables—Approximate Steel-square Price List: The Old Standard Square, Coarser Spacings along the Edges, Special Surface Finishes, Special Tables and Patterns—Octagon Scale—Brace Rule—Board Measure—Rafter Tables—Steel-square Accessories.

Human Machinery of the Past

Progress moves so smoothly in the building trades that it is recognisable only when one steps aside for the moment to survey the march. Yesterday's experience was a basis for the practice of to-day, as results obtained to-day form fresh foundations for the methods of to-morrow.

Who remembers those slow old hand shops of the past generation? Mallets and hand chisels knocked out all mortises. Ploughs, filletsters, hollows, rounds and snipes-bills hand-worked all mouldings. On square angles the old hands were safe, for every joiner carried his selected kit of brass-bound ebony squares. But once away from the sure square angle, bevelled joints were a horror of uncertainty to them. The more adventurous spirits carried mitre-squares, on which the single angle of 45° was given once for all for instant reference. Beyond this ultimate fixed outpost all was in the stream. Each new bevel became an independent problem. They set out the winders for a thousand flights of stairs, and never realised that the angle cuts of all these winders were simply standard repetitions. They had no tool that would set out the needed angles, and no language in which to speak of bevels. When the building foreman wished to hand an angle to them he had sets of templates screwed together on his job, and sent them in to the shop men as their full-size working patterns. At the yard they copied his model out on boards, set joiners' bevels to the joint angles, or made themselves wooden bevel moulds. Boring half-inch holes through these pitch boards, they added them to the stock that hung upon the wall at one end of every bench walk, and harrowed the soul of every unfortunate apprentice who chanced to roll one inquisitive eye in that direction. Their moulds were carefully preserved and guarded, for they had no tool that would record or reproduce their working bevels. Once a pattern had been lost, the angle was gone beyond recall.

Power Plant of the Present

Machine woodworking is the single step which separates those old hand shops from the machine mills of to-day. The old hand days are gone and none need regret them. No apprentice now spends his years in hand-ripping so much stuff as would form a poor day's output from a modern saw-bench. It is no longer a test of proficiency to hand-make a door in the old ten-hour working day. It becomes unfashionable to bracket men and machinery together under the single title of "Mechanics." Certainly the old joiners were cheap and excellent machines, but there are higher ambitions for the human mind. To-day we see the builders' yard plant established and advancing. The smaller speculator is frequently without yard or plant, but still draws his machine joinery from the trade mills. But larger regions ahead are still in process of exploration. Bevelled work in the shops is still unsystematised. Machine-cut carpentry on the buildings is still in its infancy.

Mind from the Men and Power from the Mains

One step carries us on from the present to the future. This section shows what is now being done by advanced builders with one tool for giving and recording angles, the steel square, and one item of power plant, the building saw-rig. Separately each is an immense advance. In combination they are ideal. The steel square is the one perfect tool for producing and recording bevels. At any time the square will duplicate an angle from the original data or from figured memoranda. The memory stores itself with useful figures that produce accurate bevels at the moment they are needed, and for this reason most steel-square men will never trouble to preserve a working pattern. Without moulds or templates the steel-square building foreman now sends in his figured bevels to the steel-square shop foreman, exactly as he sends in all his other figured dimensions. The shop foreman gives these accurate angles in words to his setter-out, or to the steel-square joiner at the bench. What was once a region of doubt and hesitation is now covered by the steel square with ease and certainty. The steel square provides and preserves all lengths and bevels. The building saw-rig executes all outdoor woodwork with parallel ease and accuracy.

Eight carpenters working by hand to the limits of their capacity will not produce one horse-power. But the builder pays the standard rate, however much the horse-power falls. The individual rates may vary according to demand and locality from 1*s.* 6*d.* to 2*s.* an hour, costing the builder from 12*s.* to 16*s.* an hour per horse-power of maximum output. But to engage human intelligence to produce horse-power is as extravagant a procedure as to set horses to supply human intelligence. Most of the large electricity undertakings supply current for power at around one penny an hour per horse-power. Already large economies are

indicated, but there are still further possibilities. Unlike the variable human machine, an electric motor demands payment in exact accordance

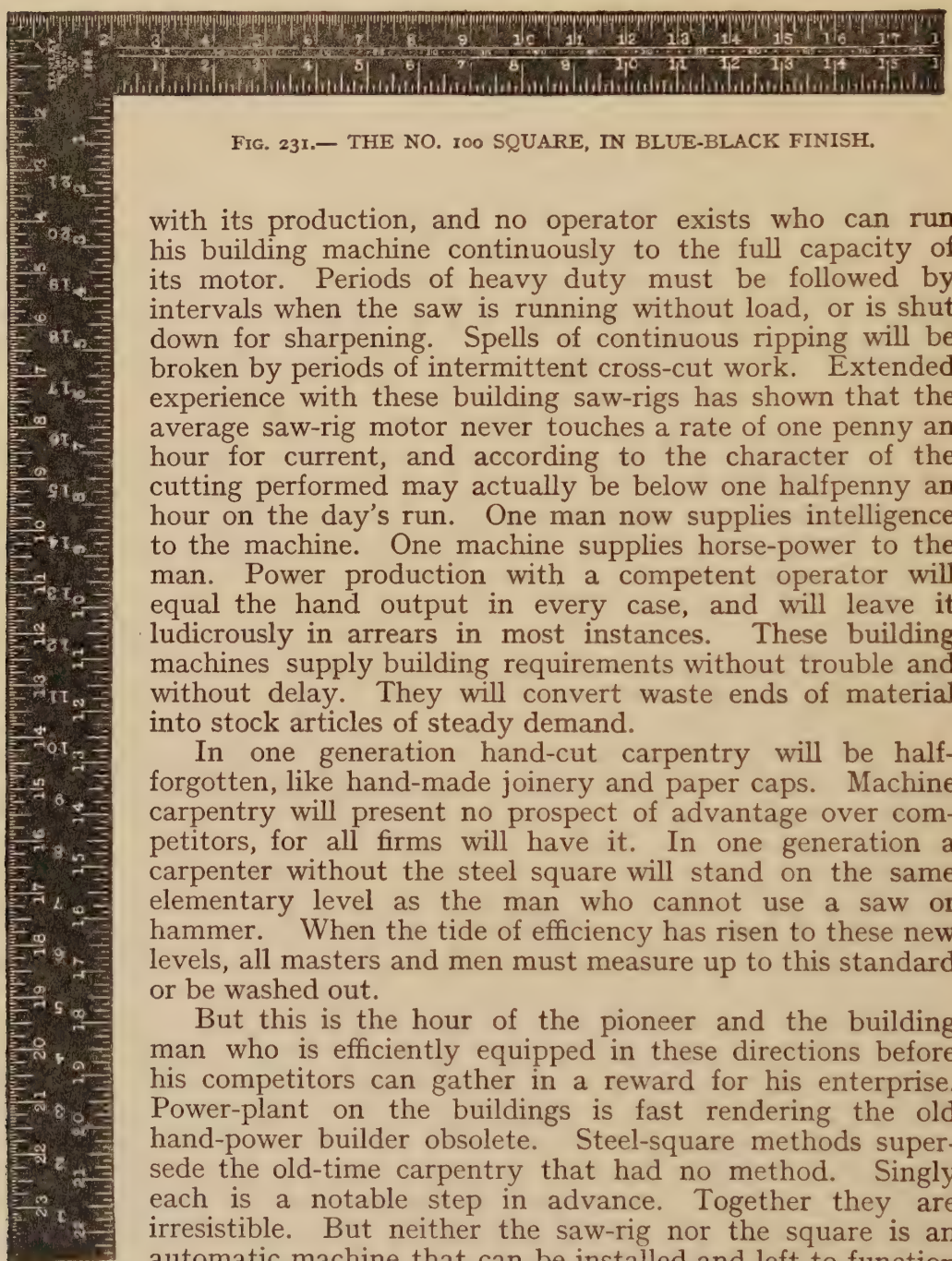


FIG. 231.— THE NO. 100 SQUARE, IN BLUE-BLACK FINISH.

with its production, and no operator exists who can run his building machine continuously to the full capacity of its motor. Periods of heavy duty must be followed by intervals when the saw is running without load, or is shut down for sharpening. Spells of continuous ripping will be broken by periods of intermittent cross-cut work. Extended experience with these building saw-rigs has shown that the average saw-rig motor never touches a rate of one penny an hour for current, and according to the character of the cutting performed may actually be below one halfpenny an hour on the day's run. One man now supplies intelligence to the machine. One machine supplies horse-power to the man. Power production with a competent operator will equal the hand output in every case, and will leave it ludicrously in arrears in most instances. These building machines supply building requirements without trouble and without delay. They will convert waste ends of material into stock articles of steady demand.

In one generation hand-cut carpentry will be half-forgotten, like hand-made joinery and paper caps. Machine carpentry will present no prospect of advantage over competitors, for all firms will have it. In one generation a carpenter without the steel square will stand on the same elementary level as the man who cannot use a saw or hammer. When the tide of efficiency has risen to these new levels, all masters and men must measure up to this standard or be washed out.

But this is the hour of the pioneer and the building man who is efficiently equipped in these directions before his competitors can gather in a reward for his enterprise. Power-plant on the buildings is fast rendering the old hand-power builder obsolete. Steel-square methods supersede the old-time carpentry that had no method. Singly each is a notable step in advance. Together they are irresistible. But neither the saw-rig nor the square is an automatic machine that can be installed and left to function

automatically. More necessary than these tools are the men that supply the intelligence. For them the future holds an open door.

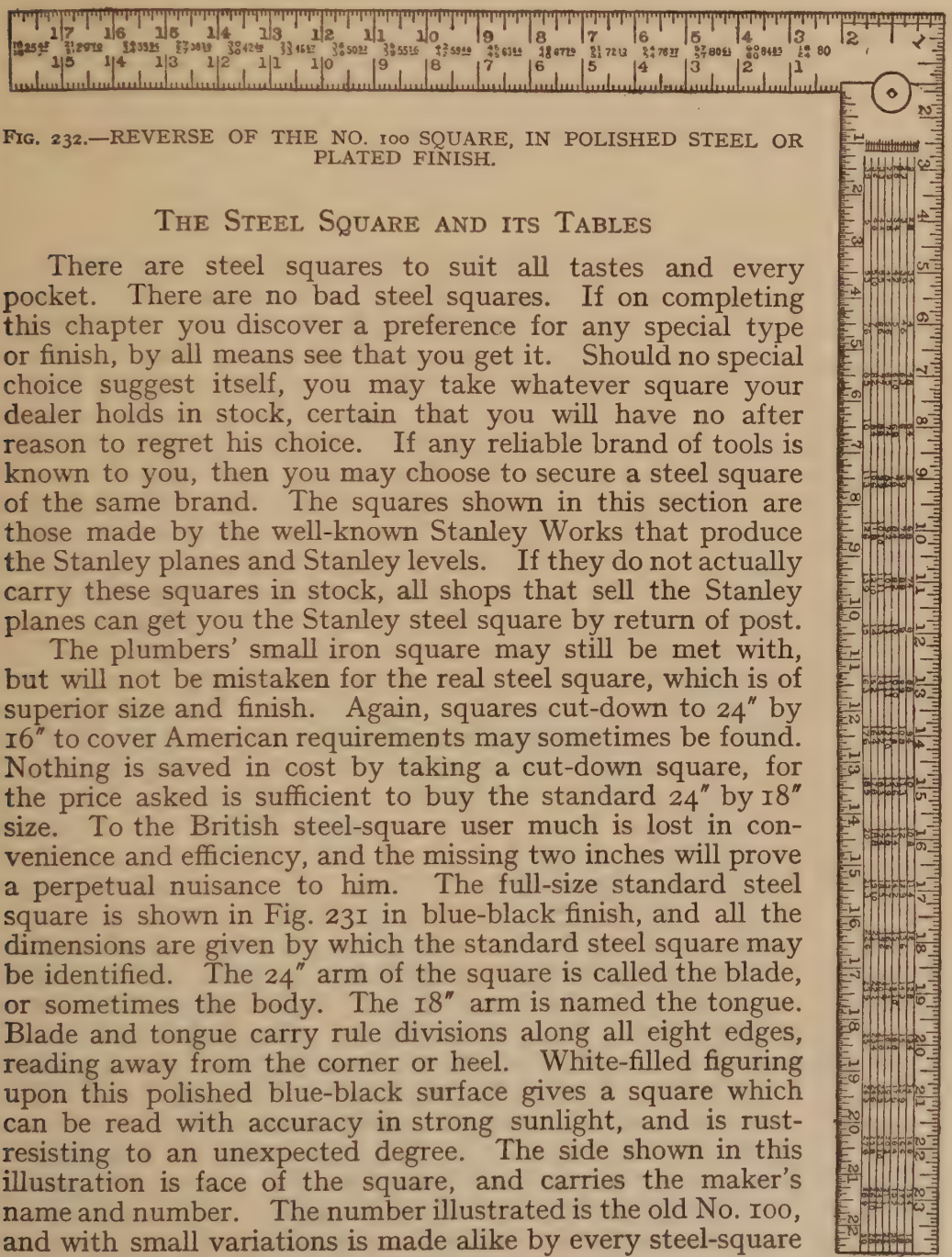


FIG. 232.—REVERSE OF THE NO. 100 SQUARE, IN POLISHED STEEL OR PLATED FINISH.

THE STEEL SQUARE AND ITS TABLES

There are steel squares to suit all tastes and every pocket. There are no bad steel squares. If on completing this chapter you discover a preference for any special type or finish, by all means see that you get it. Should no special choice suggest itself, you may take whatever square your dealer holds in stock, certain that you will have no after reason to regret his choice. If any reliable brand of tools is known to you, then you may choose to secure a steel square of the same brand. The squares shown in this section are those made by the well-known Stanley Works that produce the Stanley planes and Stanley levels. If they do not actually carry these squares in stock, all shops that sell the Stanley planes can get you the Stanley steel square by return of post.

The plumbers' small iron square may still be met with, but will not be mistaken for the real steel square, which is of superior size and finish. Again, squares cut-down to 24″ by 16″ to cover American requirements may sometimes be found. Nothing is saved in cost by taking a cut-down square, for the price asked is sufficient to buy the standard 24″ by 18″ size. To the British steel-square user much is lost in convenience and efficiency, and the missing two inches will prove a perpetual nuisance to him. The full-size standard steel square is shown in Fig. 231 in blue-black finish, and all the dimensions are given by which the standard steel square may be identified. The 24″ arm of the square is called the blade, or sometimes the body. The 18″ arm is named the tongue. Blade and tongue carry rule divisions along all eight edges, reading away from the corner or heel. White-filled figuring upon this polished blue-black surface gives a square which can be read with accuracy in strong sunlight, and is rust-resisting to an unexpected degree. The side shown in this illustration is face of the square, and carries the maker's name and number. The number illustrated is the old No. 100, and with small variations is made alike by every steel-square

maker. Distinctions between face and back of the square are not of much practical use. Both are meant for use, and the steel-square man will employ one side no less than the other.

The back or reverse of the No. 100 square is shown in Fig. 232, and illustrates the appearance of the square in plated or polished finish.

A take-down joint is indicated in the angle of this square, which will permit of the two arms being taken apart for storage or transport. Dozens of makers each produce dozens of different types and finishes, and no rigid uniformity in price can be expected. Nevertheless, within a few pence either way the table below will show what the purchaser may expect to pay for standard patterns and for variations.

Approximate Steel-square Price List

The Old Standard Square

The No. 100 Steel square with Polished Finish .	10*s.*

Coarser Spacings along the Edges

Deduct if divided only to $\frac{1}{4}''$ spacing . . .	1*s.*
Deduct if divided only to $\frac{1}{2}''$ spacing . . .	2*s.*

Special Surface Finishes

Add for Nickel-plated or Galvanised Finish . .	2*s.*
Add for Blued Finish	2*s.* 6*d.*
Add for Royal Copper Finish	4*s.*

(All special finishes with white filling to the figures.)

Special Tables

Add for Rafter Table to the Square . . .	3*s.*

Special Patterns

Add for Take-down Joint to the Square . .	11*s.*

With this table and the detailed illustrations that follow, the buyer may select his pattern and estimate his expenditure. Just as he might save a shilling yet effect no real economy by buying a dressmakers' tape in place of the carpenters' rule, so he may save one or a couple of shillings by taking dressmakers' divisions upon his steel square. These coarse spacings are better left to the stonemasons, for whom these cheaper squares are provided. Nevertheless, if nothing better can be had, any steel square is better than no square. But the special finishes are on another footing. Plain polished steel will rust outdoors and become unreadable at every opportunity, and all these finishes give a remarkable improvement in appearance, in readiness and accuracy of reading, and

in resistance to the weather. On all three heads a special finish will usually prove itself a very real bargain for its price.

Then there are the rafter tables, of which every maker has his special patterns, and here every man is free to decide according to his inclinations. With an odd 3*s*. of no particular importance, the buyer may very well obtain a rafter square, since if these special tables are found afterwards to be surplus they can always be ignored, while if urgently wanted after purchase they can never be stamped upon the square at later date. But just the same work will be done with the old No. 100 square, which contains no rafter tables.

FIG. 233.—HOW THE TAKE-DOWN JOINT SHOWN IN FIG. 232 IS TAKEN APART AFTER USE.

The take-down joint is popular and expensive. Two standard steel squares cost less than the single take-down. The take-down square put together for use has already been shown in Fig. 232. Fig. 233 now shows how this angle joint is taken apart for transport. The two separate arms pack neatly into the waterproofed canvas case shown in Fig. 234, where the square is safe from accidental scratches, is weatherproof, and is eminently portable. But all these joints are tender and must not be expected to withstand heavy falls. A drop that will leave the standard one-piece square unharmed will ruin a take-down square beyond repair. The standard square in its polished steel finish costs within a few pence more or less of 10*s*. Adding all possible extras, the luxurious buyer may specify a take-down blued rafter square at a price in the neighbourhood of 26*s*. Whatever the initial outlay upon the square, this tool will make it good to the buyer in a very short time.

FIG. 234.—THE TAKE-DOWN SQUARE IN ITS WATERPROOF CASE.

OCTAGON SCALE

The rule divisions stamped along all edges of a steel square are its only essentials. Tables of more or of less value will be found added by way of space fillers. The later rafter tables may soon prove of advantage in actual roofing, but it may be years before one of the historical tables found upon the old No. 100 squares proves of any great practical value to its owner. Nevertheless, these tables exist upon the square, and it will be well that the steel-square user should know the purpose which their old-time inventors expected them to serve. The tongue of the blued 100 square, already shown in Fig. 231, gives position and appearance of the octagon scale. Fig. 235 shows a section from this table in larger form. To avoid all necessity for counting up the spaces given on this scale, they are numbered at every fifth space, as 5, 10, 15 and upwards. This scale supplies the distances by which arris points of all octagons lie on either side of a centre line. Given any square stick

of timber to be made into eight-square or octagonal form, as shown end-grain in Fig. 236, the size of our square timber is measured in inches,

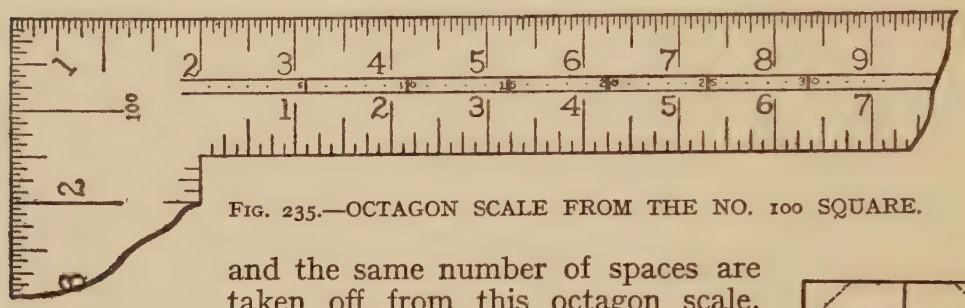


FIG. 235.—OCTAGON SCALE FROM THE NO. 100 SQUARE.

and the same number of spaces are taken off from this octagon scale. An octagon that is to be worked out of stuff that is now 1″ square will have its arris points just one of these scale spaces on either side of the centre lines. A square stick of timber that is 24″ in width has the arris lines for the future octagon just 24 of these spaces on either side of centres, and so for octagons of all other dimensions. Width of each face of the octagon is then seen to be just double this distance, or 48 spaces from the octagon scale.

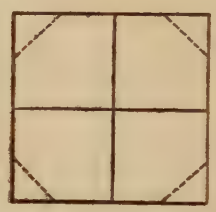


FIG. 236.—SETTING OUT OCTAGONS WITH THE OCTAGON SCALE.

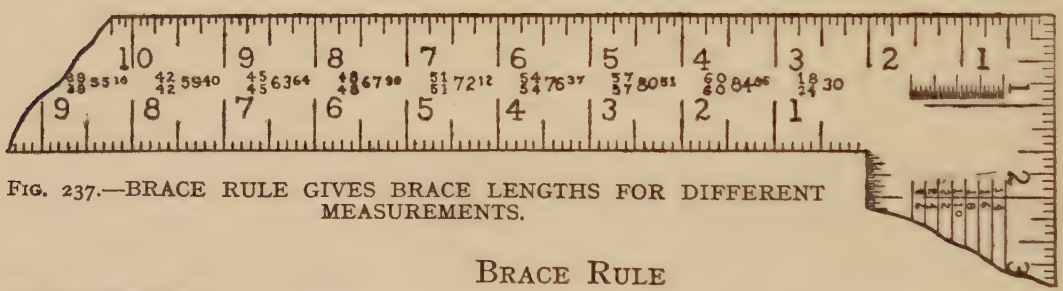


FIG. 237.—BRACE RULE GIVES BRACE LENGTHS FOR DIFFERENT MEASUREMENTS.

BRACE RULE

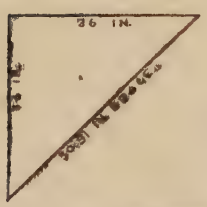


FIG. 238.—SHOWS THE TWO EQUAL SIDES AND DIAGONAL THAT ARE GIVEN IN THE BRACE RULE.

Reverse of the tongue shown in Fig. 232 gives position of the brace rule, which is shown again in larger form in Fig. 237. The three figures shown in each group are lengths of the two equal sides and the diagonal of a square-angled triangle. Then the figures shown in this table state that if a brace is to drop 36″ and must also project 36″, its length to reach diagonally across between these two points must be exactly 50·91″, as seen in Fig. 238. For the reader who is new to decimal fractions, this may be stated again as $50\frac{91}{100}$″, or 50″, 9 tenths, and 1 hundredth. A scale of hundredths of the inch will be seen in Fig. 237, set crosswise to the blade near its corner. Fifty inches can be measured off with a rule, and the 91 hundredths can be added from this scale. But the man who can

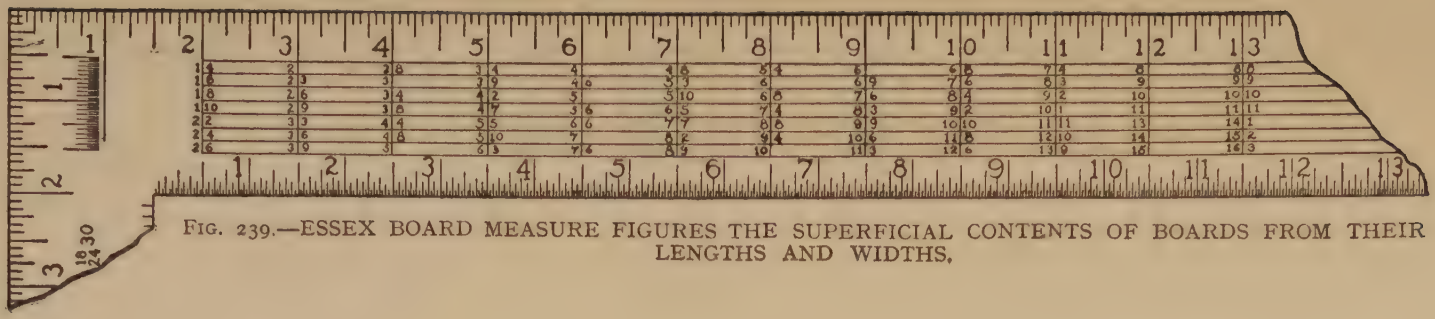


FIG. 239.—ESSEX BOARD MEASURE FIGURES THE SUPERFICIAL CONTENTS OF BOARDS FROM THEIR LENGTHS AND WIDTHS.

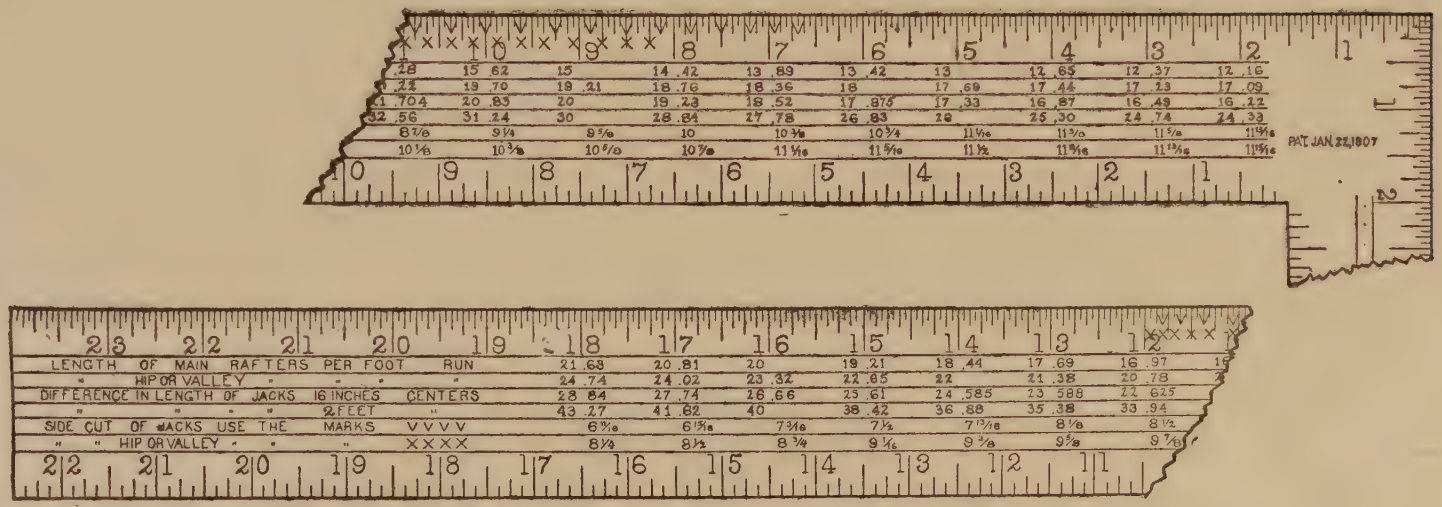

LENGTH OF MAIN RAFTERS PER FOOT RUN
" HIP OR VALLEY " " " "
DIFFERENCE IN LENGTH OF JACKS 16 INCHES CENTERS
" " " " 2 FEET "
SIDE CUT OF JACKS USE THE MARKS V V V V
" " HIP OR VALLEY " " " X X X X
PAT. JAN. 22, 1907

FIG. 240.—THE STANLEY RAFTER TABLE.

guarantee his setting-out to the exact hundredth of an inch is rare, and another scale shown in this same figure will prove of more general use. This is the scale of tenth-inches that runs along the inner edge of the tongue. Disregarding the odd 1/100th we have 9/10ths of an inch, which we take directly from this scale.

Board Measure

The great mass of figures filling the blade below this scale of hundredths is the Essex Board Measure, named from its old-time inventor. This is simply an elementary multiplication table, that gives results for feet multiplied by inches. Fig. 239 shows this table in larger size. The centre column standing below the 12″ rule mark is the key to this table. Either width of our board in inches or its length in feet is found in this column, and the same line is followed sideways till we rest under the edge rule division that shows the remaining dimension of our board. At this point, where the selected line and column intersect, will be found the superficial contents of the board in question.

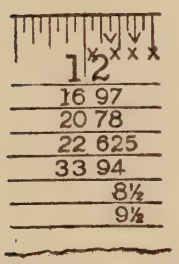


Fig. 241.—COLUMN FROM THE STANLEY RAFTER TABLE.

Rafter Table

The rafter squares substitute or supplement these older tables by one showing lengths and cuts for roofwork. That appearing on the Stanley squares is shown in Fig. 240. This table extends on the square from the 2″ to the 18″ rule divisions, and covers roofs having any of these rises in one foot of their rafter spans. The rule division figures set along edge of the blade now read as headings to these columns, and show the rise of a roof in one foot of its span. Then the pitch shown in its centre column rises 12″ in one foot of span, and is therefore of the 45° or square pitch. Rafter length is taken from the first line of this table as 16·97″ for every foot of rafter span, as Fig. 241. Multiplying this figure for one foot of span from the table by the number of feet that the rafter is required to span, gives finished length of the rafter pattern. Hip and valley length for this pitch is shown in the second line of this table as 20·78″, and multiplied by the same span provides finished length for the hip and valley. Since the figures have been stamped upon the square for a rafter with one foot span, it is plain that they may be made to lengths of rafters and hips for roofs that have any number of feet in their span. We have only to multiply the results given for one foot by the number of feet that the rafter is required to cover. The next two lines show variations in the lengths of successive jack rafters when spaced at 16″ and 24″ on centres, and will not be of much assistance to the British roofer, who is rarely allowed such spacings. But the method

employed to obtain the figures set out in this table will indicate the way in which figures may be obtained that will be correct for any other approved spacings. It will be seen that the first of these figures showing variation for 16″ centres is only the top-line figure increased by one-third, just as the spacing on centres has now been increased by one-third from 12 to 16. Again, the second result that gives variation for 24″ spacings is nothing but the top-line rafter length for one foot doubled, to provide the difference in length for two feet. The roofer who needs to use this table to obtain lengths of his jack rafters at other spacings on centres may follow the same procedure. Rafters to be spaced at one foot apart will be 14″ on centres. We have increased the 12″ spacing by one-sixth, so must increase the rafter length given for one foot by one-sixth also. Doing this for the 12″ pitch we have 19·80″, or 19$\frac{4}{5}$, as difference in the lengths of successive jack rafters. For 13″ spacings or 15″ centres, the spacing is now 12″ increased by one quarter, and the common difference in lengths of the jack rafters will be simply rafter length given in the top line for one foot also increased by one quarter. The two final lines give bevels for the jack splays and for hip and valley splay.

FIG. 242.—THE STARRETT STEEL-SQUARE FENCE.

FIG. 243.—THUMBSCREWS CLIP THIS FENCE TO THE SQUARE.

STEEL-SQUARE ACCESSORIES

The experienced steel-squareman has a prejudice in favour of keeping his square free for instant changes of bevel, but the learner has usually an inclination for something in the nature of a bevel stock that can be pressed firmly to one edge of the stuff. A slot may be ripped in timber of convenient size, and the square be secured by screws or thumbscrews within this fence. A useful fence for the steel square is shown in Figs. 242 and 243. It is

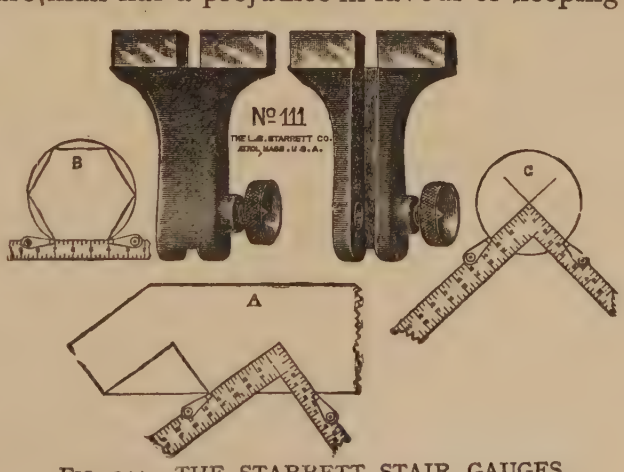


FIG. 244.—THE STARRETT STAIR GAUGES.

made accurately of steel angle bar, and can be had either in plain steel or graduated with rule divisions to match the square, thus enabling diagonal lengths to be read directly from the fence. It can be clamped in a moment across the square to any required angle as shown, and enables the same bevel to be repeated indefinitely, as in marking off the mitre-cuts for window-sills, or setting out shoulders of stair strings. The objections to this fence are that it will not give the same bevel of opposite hand without removing it from the square and re-setting. Again, simple square cuts cannot be marked while this fence is attached to the steel square. A pair of simple and inexpensive attachments are shown in Fig. 244 that meet at least the first of these difficulties. Screwed one each upon blade and tongue, they supply a fence exactly as was done by the steel angle bar. To mark the same bevel of opposite hand, as with double newel shoulders, or shoulders to a diminished stile door, the square is turned opposite side upward, which reverses the hand of this bevel without changing its setting.

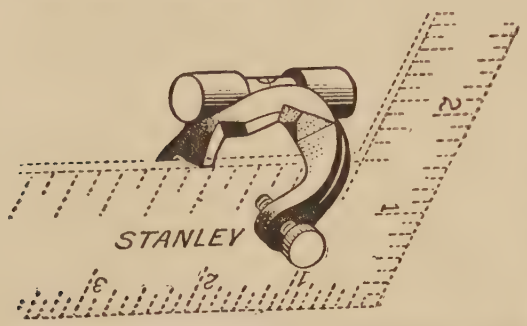


FIG. 245.—THE STANLEY TWIST-BIT AND STEEL-SQUARE LEVEL.

FIG. 246.—THE STANLEY POCKET-LEVEL FOR THE SQUARE.

Little level attachments are also made for the steel square and will be found of great value. The man carrying one of these level attachments can dispense with the clumsy 2′ wooden spirit plumb level. Clipping one of these levels to centre of the blade, we have a 2′ steel level at small cost and slight additional weight. Screwed close in the angle of the tongue, they provide a useful steel spirit plumb. Fig. 245 shows a type that screws to either steel square or brace-bit. Fig. 246 may be used independently as a small pocket level.

FIG. 247.—THE STARRETT LINE LEVEL.
A 40′ level for the waistcoat pocket.

A tool of extraordinary ingenuity is shown in Fig. 247. This is a 40′ level that can be carried in the waistcoat pocket. It will be

found extremely useful in carrying a level line over inaccessible intervals, as across opposite roof plates or between heads of erected columns which must be cut off accurately to one level. If one end of the line is made fast to the point from which it is desired to carry on the level, the line can be thrown across any intervening gap. The tube is then suspended from any point of the line, and the given level can be transferred direct to any number of points within the 40′ radius. Made of aluminium, this level weighs just half an ounce, and its pull upon the line is negligible.

CHAPTER IX

THE BUILDING SAW-RIG

By Harold Ryder

Selecting the Building Machine—The Swing-saw—Portable Cross-cuts—The Building Saw-tooth—Ripping and Cross-cutting—Building Plant for Staff, Navvies, Bricklayers and Plasterers—Stock Carpentry Cutting—Cutting Circular Work—Mitring Moulds—Grooving, Notching, Halving and Tenoning—Grinding, Sanding or Buffing—Belt Drive to other Machines—Mortiser or Planer.

Selecting the Building Machine

One generation ahead an inquiry for the best machine for building use will have the same odour of antiquity as a discussion on the best machine to equip a machine joinery mill. In those days there will be as many useful types of machines made for the buildings as for bench work, but machine carpentry, like machine joinery, must make its beginning before it can pursue its development. It may well begin with the same primary converting tool, the saw.

The type of saw will be indicated very closely by building requirements. If any contractor proposes to break down his timber from imported balks on the site, plainly a power-feed bench circular or band re-saw will be needed. Unless British-sawn timber is specified, the builder will usually buy his building timber in the sizes that he intends to employ, and the bulk of his building sawing will then consist of square or diagonal cross-cuts. For cross-cut work a cross-cut saw is indicated.

The Swing-saw

The pendulum cross-cut or swing-saw is made in sizes up to the frame that swings a 30″ saw and cross-cuts 12″ material. Any motor can be built in or belted to the saws, and the heaviest cutting will be carried out easily with an ample reserve of power. But the very size and power of the standard mill swing-saw limits its portability severely. This type is powerful but not portable. Being standard, it is an inexpensive type, but its cheapness carries corresponding disadvantages. The saw swings back and forth in one unchangeable direction. There is only a single sawpath, and if other than a square-angled cut is required, we have then to present the stuff to the saw at a correct bevel. Making different cuts, the stuff may require to lie at different times in nearly

any position around the circle of which the saw forms the centre. To cut 20′ material calls for a clear circle of 40′ diameter.

There is another impediment with the swing-saw. As it has no horizontal adjustment around the circle, so it has no vertical adjustment that can be used to regulate its depth of cut. All adjustments of this type are to be made by packing up upon the tables, or by substitution of a table carrying the special depth that is needed. Generally three or four tables varying in height by 1½″ steps will serve all purposes, leaving finer adjustments to be made by packing up upon the tables or by substituting saws of different diameters.

There is still another handicap under which the swing-saw works. As its name implies, it swings from a pair of overhead pivots. Distance from these pivots to saw spindle will usually run to about 6′. Distance from these pivots to under edge of the saw may then be about 7′. Then the saw teeth swing forward to make their cuts in a circle of 7′ radius. Where the stuff is cut completely through, this motion is of no importance, but it prohibits cross-cut grooving or trenching upon wide stuff. For narrow work, such as halving 4″ by 3″, this circular dip is of smaller importance though still present. Halving these 4″ by 3″ plates, the central angle between position of the saw when cutting at the edge of stuff and position when working at centre of the material will be 2″ in 7′, or 1 in 42. Then the tangential angle from edges of the halving to its centre will be exactly one-half of this central angle, and with sufficient accuracy for our present purposes may be estimated as 1 in 84, or 1/42nd of an inch of dip in the centre of this halving. This is even less clearance than will be given by a carpenter who knocks out these halvings by hand, and for narrow material the radial dip evidently may be neglected. But as we move ahead to wider material this dip becomes more noticeable. Grooving 8″ stuff under the same conditions, the central angle is now 4 in 84, and the tangential angle roughly 2 in 84, or 1 in 42. Distance from edges of this stuff to the centre is now 4″, and the cut dips at approximately 1 in 42, or about 1/10th of an inch. Evidently if this dip can be accepted, nothing very much greater can be tolerated, and the swing-saw dip increases rapidly with increased width of stuff.

Estate developers, or the big contractors who buy in shiploads for use and stock, may very well store this material at one central timber dump near the swing-saw that will convert it for use when called for. The smaller buyer will usually purchase for immediate use and prefer to avoid this second handling of his stuff. He must then take delivery of his timber direct to the building site, and arrange for plant that is sufficiently portable to follow his operations from house to house. Sometimes the smaller speculator will decide to handle the whole of his building woodworking operations upon his single building machine, rather than accept the delays, inaccuracies and indifferent materials of the hustled trade mills. Choicer pieces from his carcassing timbers may be broken

down upon the building saw-rig, and will produce the frames that he needs. At short notice his building machine will work up the seasoned material for use.

Portable Cross-cuts

Smaller and more convenient machines may be had that will carry a 12″ saw as their normal equipment, and will swing a 16″ or 20″ saw upon emergency. To secure portability and compactness, the overhead swinging pivots are abandoned, and the saw is now advanced on slides in a level path. Level grooving can now be done upon the widest surfaces, as to shelving standards or stair strings. Generally these horizontal slides are mounted in a bracket carried by a post set at rear of the cross-cut table. An adjustment for depth of cut is secured by making this bracket rise and fall upon its supporting post, and the single table now gives all the varying depths of cut. But a second adjustment for angle of the cuts is provided by making the post itself revolve upon a footstep. All timber now lies in one uniform position on the table, and the cut required is secured by swinging the rear post around till the saw moves forward in the path required. Sometimes these portable cross-cuts will carry a 6″ planer worked from the one motor. In other cases this accessory can be dispensed with. Whether issued as standard or ordered as an extra, a 2″ extra length of saw spindle is an inexpensive provision for the building saw-rig, that will open the path to many useful attachments. With this essential secured, it will be found in emergency that the selected machine has many unsuspected possibilities in reserve. Since the tool is to handle carpenters' work, it will best be handled as a carpenters' tool by a carpenter.

The Building Saw-tooth

The old peg-tooth that is generally supplied as a cross-cut has one merit that can never be utilised, and fifty defects that obtrude themselves at every minute. Since its teeth stand at the equal 60° angle back and front, the saw will cut equally well or equally badly if revolved in either direction. But it will rip nothing heavier than 1″ stuff, and must be discarded for every job where rips and cross-cuts alternate.

The rip-saw tooth gives a better saw even for cross-cut work, but has a special danger when transferred direct from a saw-bench to the swing-saw frame. Used in a bench, all cutting is done upon the upper segment of the saw, where the revolving teeth strike forward at the advancing material and repel it. But mounting the same saw on a swing-saw frame, all cutting is now executed by the lower segment, where the teeth are revolving in the same direction as the stuff advances. The hooked teeth may now snatch at material and carry it forward faster than the saw can cut. As a first precaution, all ripping executed on the pendulum saw should be done with the table in its highest possible

position. As a second security, all short rips, such as wedges and sprockets, will be cut with the saw swinging freely, and a rear fence bradded down to the table that will prevent stuff being overridden by the saw and slung out at its rear. As a third necessity, less hook should be given to the teeth than is customary with a bench-saw. For the average saw and average run of building timber, a rip-saw tooth having not more than a 2″ hook will be found most suitable. By a 2″ hook it is understood that face line of every tooth is directed to a point 2″ to rear of the saw centre. This type of tooth, sharpened with a good side bevel or fleam, will cover building requirements efficiently. It will neither burn in a ripping cut and call for endless attention, as is the habit of the old peg-tooth when put to general utility work, nor snatch at material faster than it can be cut, as is done by a standard rip-saw tooth when mounted on a swing-saw frame.

Ripping and Cross-cutting

A range of saw sizes to the uniform tooth type will simplify matters for the saw sharpener, and will cover both straight ripping work and all the square and diagonal cross-cutting that is called for on the buildings. Long rips are executed by feeding stuff to the saw, keeping one edge in contact with a fence, as is done on a saw-bench. On light timber the frame may be allowed to swing freely, but for heavier rips it may very well be latched hard back to the rear, to prevent it snatching at a knot and running forward unexpectedly. In cross-cutting, on the contrary, the material is rested against a fence set to the rear and adjusted to produce the square or diagonal bevel that is desired. Cuts are made in this case by drawing the swinging saw through standing material. Short straight or diagonal rips up to about 2′ in length are best handled with the rear fence and swinging saw frame as with direct cross-cuts. For these short rips the swing-saw reveals an unsuspected efficiency when compared with the saw-bench on its own ground. Where the bench will cut but one square or diagonal angle at a time, the cross-cut table may be fitted with a number of temporary ripping and cross-cutting stops without any one fouling the others. If six separate cuts have to be put upon complicated patterns, six fences may be bradded down to the table at correct angles, and without marking the material all six cuts can be made in immediate succession on the swing-saw, without necessity for putting the whole stack of stuff six times through six separate operations as must be done when cutting on the bench.

Building Plant for Staff, Navvies, Bricklayers and Plasterers

With machine-cut material, the provision of building offices is an affair of hours. Office furniture, such as plan drawers and stools, can be run off in short order on the same machine. Building sheds and navvies' tool boxes are reduced to a cutting list and a spell of hammer-and-nail

work. In seconds only our building saw-rig will cut heavy balks correct to lengths and bevels for shoring adjoining buildings or bracing deep cellar excavations. Gantry timbers are snicked off on the saw like threads. Light pages or trench wedges are turned out in quantity for the navvies, and folding wedges for strutting or dead-shoring. Very early in his job the steel-square man may determine to standardise one uniform bevel for every wedge that is cut upon his contract, such as the 5″ in 24″ angle. Any random couple of wedges that come handy, whatever different purposes they may originally have been cut for, and however much they may vary in length, width or thickness, can then be paired up in emergency and put to instant use as an accurate pair of folding wedges. Edging boards may be needed to retain the concrete to circular road or path corners, and the swing-saw will kerf the heaviest material till it is capable of taking the sharpest curves. Setting-out, levelling, and path or curb edging pegs will be ripped and pointed with the saw swinging freely, and the builder soon finds its usefulness in equipping the bricklayer. With the swinging frame at rest 10′ measuring rods are ripped. With the frame swinging freely we cross-cut stuff for face, ledges and braces of mortar-boards, and the ready-cut material is knocked up in quick order. And the building saw is an extreme economiser of building material. A 6″ waste end of 4″ by 2″ or 4″ by 3″ will cut a dovetail sill block to which the window boards are fixed. Even 4″ ends will rip 3/8th wood pads for speculating work. Where joists of different depths are supported upon a single wall, the bricklayer may be made to pack up to the new level, or our waste ends will cut packing blocks that will brad to the under edges of the shallow joists, and will adjust all joists to one uniform floor level, without disturbing levels of the brickwork. Then there are the 10′ to 14′ batten ladders. A thousand times in the course of the day men will require to get up just another scaffold, or to mount from floor to floor by just another story. Carpenters will employ these ladders before the stairs are fixed. Plumbers and tilers will utilise them upon the roofing scaffold. Painters will employ them for first-floor window work. Carpenters will reach the lead flats over bay windows by their aid. The labourers will carry bricks up these ladders to single scaffolds set upon the floor joists or the concrete floors. And these ladders are very cheap. Two 14′ lengths picked from the 3″ by 2″ stack produce each ladder. The saw rips and cross-cuts 2″ by 1″ staves, and if desired will also notch the sides. A handful of nails constructs each ladder. They are safe under load, and have a remarkable life as compared with bought pole ladders. The foreman who has once found a day's work for an idle man in equipping his contract with batten ladders, will never from choice be found without them. Stuff is cross-cut and ripped upon the saw for plasterers' plant, and spot-boards and spot-stands are produced. Feather-edges are ripped, and running rules got out to width and thickness, from stock deliveries of building timber.

Stock Carpentry Cutting

Sprockets or false feet are got out in advance for carpentry stock. Trap hatches are cut, and trap hatch linings grooved and tongued on the saw. Tank casings and covers are put in stock, and when wanted have only to be carried to position and screwed together at the angles. Tank bearers and wooden cantilevers are cut to requirements in advance, and with all this work the real utility of the building saw has not been reached. When needed, these saws will rip any section that does not exceed about 4″ in depth. They will rip the tusk tenons for trimmer joists, and will cut the keys or wedges. They will cut out rough strings for concrete steps or stairs. When reached they will handle all the diagonal cross-cutting rips, such as rafter cuts and jack splays that are characteristic of building work. Early in the job all roofs are cut and put in stock till needed for erection.

Cutting Circular Work

Without any further equipment, all external circular curves are cut, whether to 2″ or to 20′ radius. Turning pieces for the bricklayers are got out true to curve. Circular or segmental centres or drums are also cut with the same saws. Swept rafters for segmental or circular-headed lead dormers are cut with no more trouble. The swing-saw handles all external circular curves with much better results than are obtained from the band-saws.

Mitreing Mouldings

But other types of saws may be run upon the same spindle and will introduce new possibilities. First of these is the fine-toothed mitre saw, with which architrave mould may be squared off to floor line and mitred up for angle joints. Fixing architrave then becomes only a matter of nailing up the stock ready-cut material. Cornice moulds to dormers and similar wood finishings are all cut to stock sizes in advance of requirements on the single mitre-saw.

Grooving, Notching, Halving and Tenoning

But other equipment with further possibilities is provided for by the extended saw spindle. Wobble-saws may be run upon the swing-saw frame, and are adjustable to produce grooves of any desired size. As an instance, with a single saw of this type grooves can be ripped or cross-cut to any width from $\frac{1}{8}$″ to 2″. Double expanding saws do something in the same direction, but with smaller range. For example, the saw that contracts to cut a groove of 1″ width will open out to form a $1\frac{3}{4}$″ groove. Then there are the special trenching or grooving heads which carry side cutters and small planer knives. The same side plates will carry any pair of knives from $\frac{1}{2}$″ up to 2″ in width. Again, there is

the Huther type of expanding dado head. This consists of a pair of saws with so many internal cutters sandwiched between as are needed to make up the cutter width required. These groover heads have the special advantage of allowing a mitre-saw to be included anywhere in the sandwich, allowing stuff to be grooved and cross-cut at the single pull. Where dormer ceiling joists are to be notched to a batten, the single original saw will cross-cut them to length and rip the battens. Putting on one or other of the special groover heads, a single pull of the saw-frame makes the notch. Perhaps on cheaper work the floor joists also are to be notched. Nothing but adjustment for the depth of cut is needed before this can be done. It may be preferred to substitute the old ship-lap for the cheaper batten notch. We cant the cross trimmer on the saw table to make its notches die out at half-depth of the joist. On ceiling joists we can allow the notch to die out at the under edge of the stuff. The plain saw cuts all ends of the joists to fit either of these notches. Stub or through tenons may be called for on framed partitions or on ashlar studding. The single pull cuts one side of a tenon up to 2″ in length. A second pull completes the opposite shoulder. Tenons of 4″ length are made in a couple of pulls at the saw-frame. If factory or warehouse stair strings are to be housed for treads, one adjustment for depth and a second for bevel will be needed, and the same groover head then commences and completes each groove at a single pull. Plates are to be halved square across. Two pulls with the 2″ cutter head clear out the halvings for a 4″ plate. Saw-stool heads are to be notched to receive the legs, and thirty complete heads can be turned off the saw in ten minutes. The bricklayer calls for batten ladders and these cutter heads will make their notches. The painter asks for step ladders, and a head of appropriate width will house the sides to receive all treads. Jamb linings or linings for serving hatch or trap hatches may be wanted. Set to about 3/8th width, this equipment grooves the head and tongues the jambs. Using a spacing collar which the saw will cut, we place it between the saw and the groover, and can now groove the heads and cross-cut them to length at the single pull. Setting the mitre-saw between two 3/8th groovers, we now tongue a pair of jambs at a single pull. Assembling a wider set of cutters on each side of the central saw, we can then cut two complete and separate halvings at each swing of the saw. Many other special results can be obtained, but the sawyer who has once investigated the possibilities of his tool will find that every problem suggests its own solution.

Grinding, Sanding or Buffing

Taking off the groover head, we may replace it with a 10″ by $\frac{3}{4}$″ emery wheel. Many trades will be glad to make use of this grinder. The bricklayers will appreciate its aid in keeping their iron chisels in keen cutting condition. The carpenters will secure cleaner grinding than

is obtained from most trade grinders, free from the tendency to burn the tools that characterises most grinding that is secured from the emery wheel. A tilted block bradded across the lowest saw table determines the grinding bevel. The wheel is pulled forward, swinging from side to side of the iron that is being ground. Actually again this grinding is part of a circle of 14′ diameter, but even on a 2¼″ plane iron a 14′ circle shows no perceptible variation from the straight. Since the wheel brushes along the grinding bevel touching only at one point, the iron has time to dissipate the heat received before the wheel again returns to the same spot. Burning is much more unlikely than with any other form of emery grinder. As it is possible to grind tools, so a similar wheel will gullet all saws where this is necessary. The gulleting of its own saws is only a side-line with the swing saw, and it will not be expected to rival special sharpening machines that cost twice as much as the swing-saw and its whole equipment. But it will keep the saws in order throughout the job, and at end of the contract will render instant assistance to the man who is clearing a batch of timber that the scaffolders have filled solid with nails. As the nails run down the saw-teeth, the gulleting wheel will bring them up to working condition again.

A sanding disc or buffing wheel can be run upon the same spindle. A polishing head can be fitted which will remove rust from the outdoor tools in very short order. The building sawyer will make many other discoveries to meet the problems that are presented to him, but when the last possibility of his own machine is exhausted, there still remains one final opening. The saw will cut itself a circular wood pulley which will run upon its own spindle. To this pulley any other light machinery can be belted up. Sometimes a screwing machine for fitters or electricians can be operated in the slack spells. A mortising or boring machine can be belted up for joist and partition mortising. The power behind a saw is ample for one of the smaller planers, or a combined surfacer and thicknesser, allowing surfacing, truing-up, bevelling and rebating to be executed. The smaller speculator with the saw and planer can then rip his solid frames from selected building deliveries, can face up his stuff, rebate, tenon and slot-mortise it, leaving only the moulds to run by hand, and even here the machine will help by knocking off the arris in readiness for moulding.

CHAPTER X

USING THE STEEL SQUARE FROM THE FOUNDATIONS (CONCRETOR AND EXCAVATOR)

By Harold Ryder

Shoring for Demolishments and Trenching—Flying Shores by the Twelfth-scale Method—Raking Shores to a Reduced Scale—Getting the Best Shores from Stock Material—Gantries with Horizontal Shoulders—Strutting with Vertical Abutments and Stepping the Square—Gantry Staging to the Foot-span Method—Lengths by Figuring—Concrete Steps and Stairs *in situ*.

Shoring for Demolishments and Trenching

Everything that can be known of the steel square will not be picked up at a single sitting. The steel square would not be worth learning if there were no more to it than that. But before this chapter is completed the reader will have a firm grasp of steel-square methods, and will see sufficient still before him to make the subject well worth continuing.

Every carpentry beginner knows enough to measure off the width of a board with his foot rule. The steel square is stamped with a foot rule along each arm and measures off bevel cuts in inches just as the single foot rule measures widths. Any two figures used one on either arm will measure off a bevel that can be repeated with complete accuracy at any time when it is needed. The figures producing common bevels are carried in the memory or can be jotted down on paper, and every time that the same figures are set upon the square, the same bevels will be marked off along its edges. As a second step, we shall see that the steel square will also supply the figures which produce its cuts. As a third point, the square will provide the lengths to which the timbers must be cut. But all its work is handled with the foot rule measurements, and anyone who can manage a foot rule can handle the steel square.

The Pyramid builders placed the stocks of their squares to one edge of their stuff, and marked off along the blade, and to this day no other method of using a square angle is known to many men. The steel square is an excellent 2′ square when used in this way, but this is only the beginning of its possibilities. The square may also be placed so that the stuff runs diagonally across between two figures set on opposite arms, and supplies the missing third side of the triangle. In this position any two separate measurements may be made along opposite arms of the square at one time. Then two sides of the triangle are already known, and the angle contained between them is also known. With these

three facts given, all lengths and angles about the given triangle are also known. As already shown in the steel-square details, one side of the square is divided into inches and sixteenths for use as a plain foot rule in full-size measurements, and then has a capacity of 18″ by 24″. The other side, divided into inches and twelfths, can also be used as a simple foot rule as before, and can next be employed as a twelfth-scale to show feet and inches. Then simply by placing this twelfth-scale to the timber, lengths and bevels can now be read off for angles measuring up to 18′ by 24′. Since two measurements are set on opposite arms at one time, two opposite bevels will be given at one setting. Since the angle between the opposite arms is square, if these two cuts are placed together they will complete the square angle between them.

Where a town site is to be cleared, the adjoining properties will usually need shoring. Rakers to a flying shore, as shown in Fig. 248, may be needed, and the steel square sets them out correct to length and bevels in a single minute. The height is already known to which points of these rakers are to rise. Generally this point is opposite the next higher floor level to provide a solid abutment, and in the case illustrated to the left is 10′ 6″. Distance run from face of the wall piece to the point where these rakers pitch upon the horizontal shore is also known, and is 16′ in the figure. Then, using the square as a twelfth-scale, we take the 16′ of run upon the tongue and the 10′ 6″ of rise upon the blade. Marking by tongue and blade, we have cuts that are correct for the bottom and top of this shore. For the raker measurement we need to find length of the missing third side of the triangle. We place these same figures to one edge of a straight board, just as if it was proposed to mark the cuts there. Chisel-striking the points which now rest upon the board edge, we read off this distance with the steel square as point-to-point length for the rakers. In the present case it is about 19′ 1½″, and the rakers can now be set out and cut correct to length and bevels. There is no compulsion in the matter, and the square gives exactly the same results in either way, but it is recommended that for his own convenience the steel-square learner should make a practice of taking horizontal figures on the tongue of his square and vertical measurements upon the blade in every case where this is possible. No perplexity between the pair of cuts can then arise. The rise or vertical measurement is always set upon the blade, and the rising or plumb cut is marked there. The horizontal or seat cut is found upon the tongue, where the horizontal or run figure has been used. The square will not object to being used with either arm vertical, but a rule of this sort will save the learner considerable difficulty in identifying his cuts. The method just shown is the first system to which the steel square was used. The method is exactly like that of the full-sized mould which it superseded, and the square is used just like a mould to one-twelfth scale. The advantages of this first method lie in its speed. Its disadvantages rest upon the fact that the square has been used as a scale. If the actual diagonal measure-

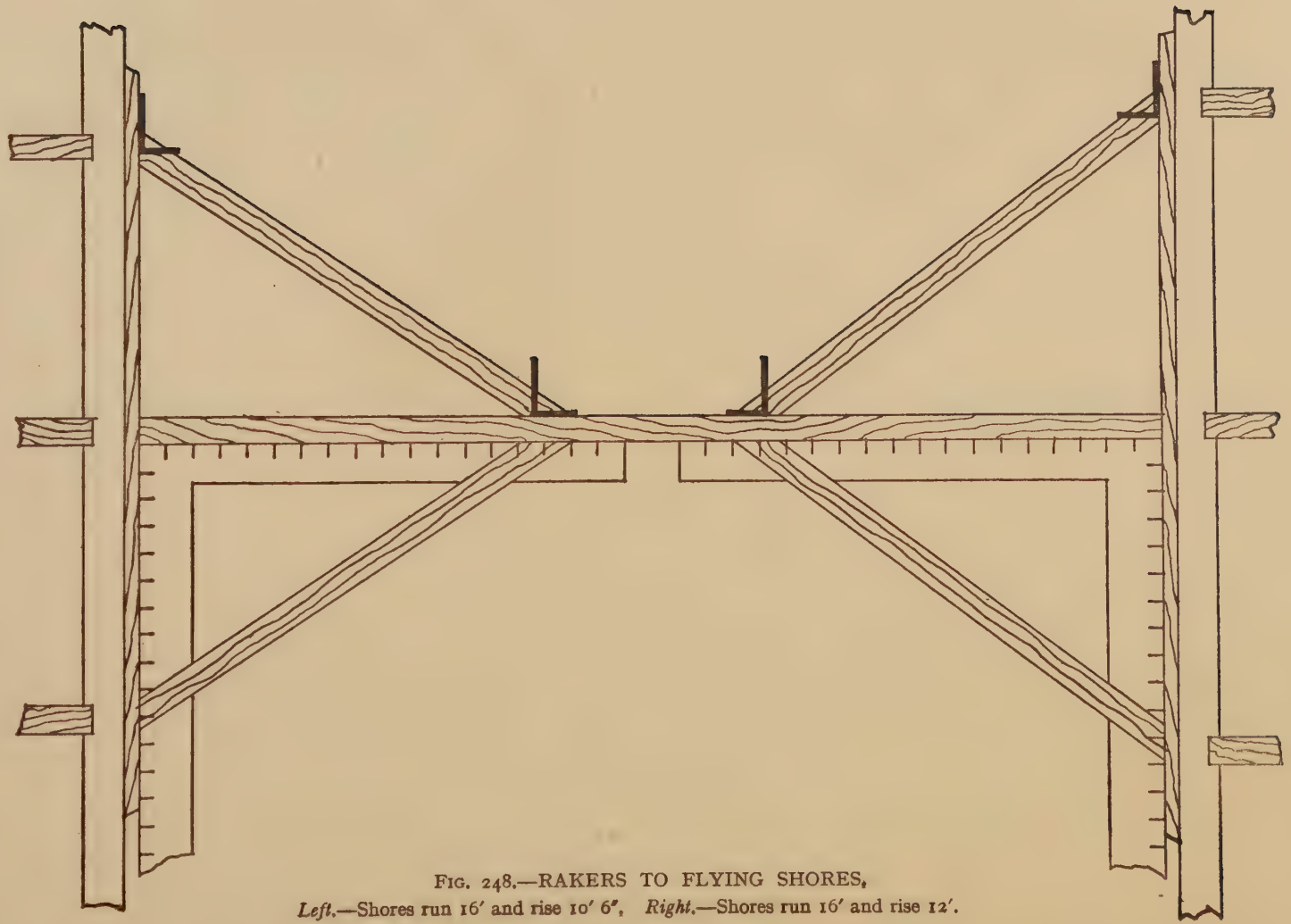


FIG. 248.—RAKERS TO FLYING SHORES,
Left.—Shores run 16′ and rise 10′ 6″, *Right.*—Shores run 16′ and rise 12′.

ment has been made correctly within half of one of the twelfth-inch divisions, since these twelfths are representing inches, our measurements are actually no closer than to the nearest half-inch.

For shoring and similar work this degree of accuracy is quite sufficient, and nothing but the later methods of steel-square use can show the same speed and greater accuracy. With our first pair of working bevels, the advantages and hindrances of the permanent fences will present themselves for illustration. If an angle-bar fence, carrying another twelfth-inch scale such as that already shown in Figs. 242 and 243, is clipped across the square from 16′ to 10′ 6″, then instantly the raker length may be read off direct from its scale, and the fence itself may be used as a bevel stock to mark off top and bottom bevels. But so soon as this has been done the edges of the raker must be squared across for cutting, and the fixed fence is simply an encumbrance. A second shore is shown to the right of this figure, and the reader may mark off its length and bevels as his first steel-square work.

Raking Shores

Shores of any pitch may be needed, but the same original method still holds good. A raking shore may be needed to rise 30′, with only an 8′ horizontal run. Neither arm of the square contains the figure 30, so we halve both given dimensions to obtain figures that can be found upon the square. This leaves the cutting bevels unchanged, for plainly 4 and 15 will give precisely the same cutting bevels as 8 and 30. Then 4 and 15 used upon the square gives the cuts for this raker. But halving the two figures has also halved the distance between them, and 15′ $7\frac{1}{2}$″ which we read off as the diagonal distance from 4′ to 15′, is only the half-length of the actual shore. Doubling this length we get the proper point-to-point length of 31′ 3″ for this raker. With this length measured off upon the timber, we mark its plumb and seat bevels with 4 on tongue and 15 on blade. Where the sole piece has been made to fall toward the building, we read off its angle of fall with the steel square, and set off this angle again from the level seat line. Where double or triple shores are wanted, we repeat the same operation with the new and separate runs and rises. The second shore may have a 9′ run and 40′ rise, when plainly 4′ 6″ on tongue and 20′ on blade will supply its cuts without further trouble. Distance measured off on the square between these points is again the half-length of this shore from point to point. The third raker will usually consist of a jack shore and its rider. If the jack shore rises 5′, while its rider is to reach to the 50′ level, plainly the rise of the rider is now 45′. Its rise figure is greater than that of the second raker, but its horizontal run will usually be less. This run can be measured in place when the second shore is pitched, or can be had in advance by figures if required. The jack shore will have the same pitch as the second raker which it rests upon, and so will be 9′ in the 40′ rise,

or 4′ 6″ in 20′, which is $4\frac{1}{2}$″ in 20″. But our jack shore has a rise of 5′, or 60″, just three times the 20″ figure. Then its run will be three times $4\frac{1}{2}$″, or 1′ $1\frac{1}{2}$″ less than the second raker, plus the necessary allowance for thickness of the timber. Then cutting figures for the rider will be about 9′ on tongue and 45′ on blade, depending on the size of the timbers. With rise and run figures, lengths and bevels are laid out as before.

Getting the Best Shores from Stock Material

Sometimes the problem may be presented to us in another form, and we may require to obtain the best possible shores from stock lengths of stuff. If only 36′ balks are to be had, then very certainly no single shore can be set up to make a 40′ rise. We find what actual runs and rises are available by halving the length of our timber to get manageable dimensions, and chisel-striking 18′, this half-length, on one edge of a board. Passing opposite arms of the square through each mark, any pair of figures that can be read off at one time will give the cutting bevels for a shore of this length. The pitch that seems most useful can then be adopted for use. Keeping to the original 4′ on tongue, we see that about 17′ 6″ on blade intersects at the length measurement. These figures give the true cuts for a 36′ shore running 8′ and rising to the height of 35′. Reducing the tongue figure to 3′ sharpens the pitch considerably, but has little effect on the rise figure, which we now read off as about 17′ 7″ for half-rise, giving an actual rise for the 6′ run of 35′ 2″.

Gantries with Horizontal Shoulder-cuts

Sometimes a crane gantry is to be carried out over an excavated area on trusses, such as shown in Fig. 249. At other times an overhead rail gantry will be put in to convey muck wagons to a barge dump. Main-line wagons are sometimes brought in across a low-lying valley direct to a factory site. On levelled ground these trusses will all be made to one dimension. On falling ground the head and sole lengths should remain standard, and the position of the post shoulders. All difference for the differing levels will be made by altering lengths and bevels of the raking side posts. If an 8′ cap and 12′ sill are used throughout, then plainly every post can be placed 2′ out of plumb, whether on high trusses or on low. Where a bent is to be 12′ in height between shoulders, then 2′ on tongue and 12′ on blade will give the shoulder cuts. Since 2″ is not of much use for marking wide shoulders if placed to the near edge of our stuff in the normal manner, we may very well set these figures to the far edge as shown in Fig. 249, to obtain a better marking bevel. The distance between these two figures on the square is about 12′ 2″, which gives our length to measure off along one edge of the post between top and bottom cuts. Should the ground rise 6″ from position of this truss

to that of the next, then plainly the following truss must be made with 6″ less of vertical height, to maintain horizontal stringers and a level track. Then the blade figure is now 11′ 6″ with the same 2′ on tongue, and so for all alterations of ground level in succeeding trusses. Unlike the building shores which run from level soles to a plumb wall-piece, these gantry posts stand between a level sole and level cap, and will therefore employ only the level or seat cut. The steel-square man who has already made it his practice to take horizontal-run figures on the tongue wherever possible, will have no difficulty in selecting the shoulder cut that is called for.

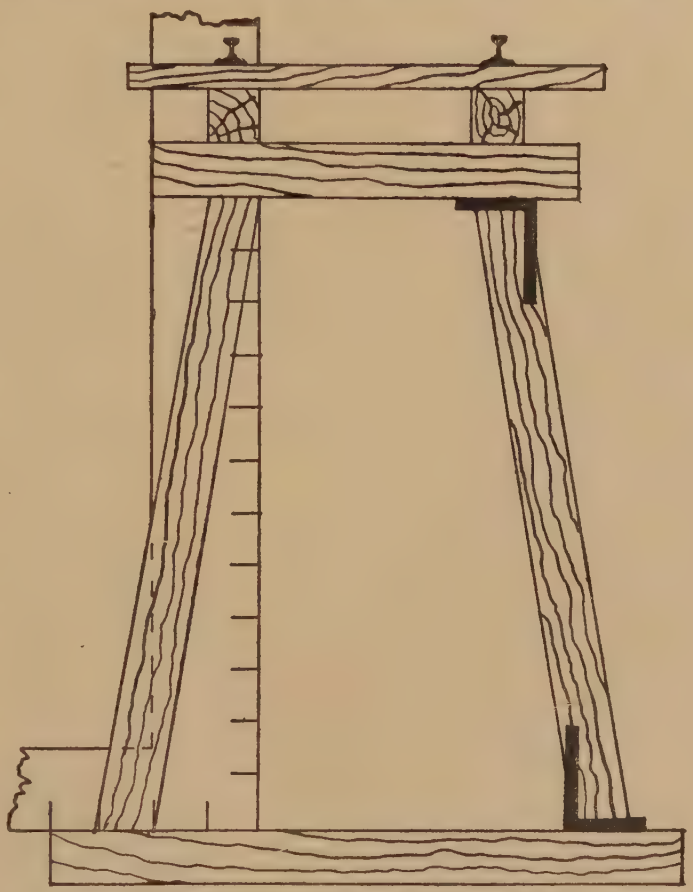


FIG. 249.—CUTTING RAIL GANTRIES WITH THE STEEL SQUARE, USING TWELFTH-SCALE FIGURES.

STRUTTING WITH VERTICAL ABUTMENTS

Rakers or braces may be needed for heavy trench timbering or for coffer-dams, and may very well be used to illustrate the second method to which the steel square was used. We take the run and rise of our braces as before, and set out the brace cuts with the same figures. In place of measuring across the diagonal between these points at one-twelfth scale, and straightway using these figures to set out our lengths in full size, we recognise that the figures which we actually have upon the square are really one-twelfth of the full actual measurements. We then proceed to step the square containing these figures up the timber, just as a pitch-board is stepped up a stair-string. Stepping twelve times, we multiply our twelfth-scale by twelve, and so secure full-size results. Walings in a wide trench are 10′ apart horizontally, and have 4′ of vertical height between them. A shore is to cut across from the waling of one

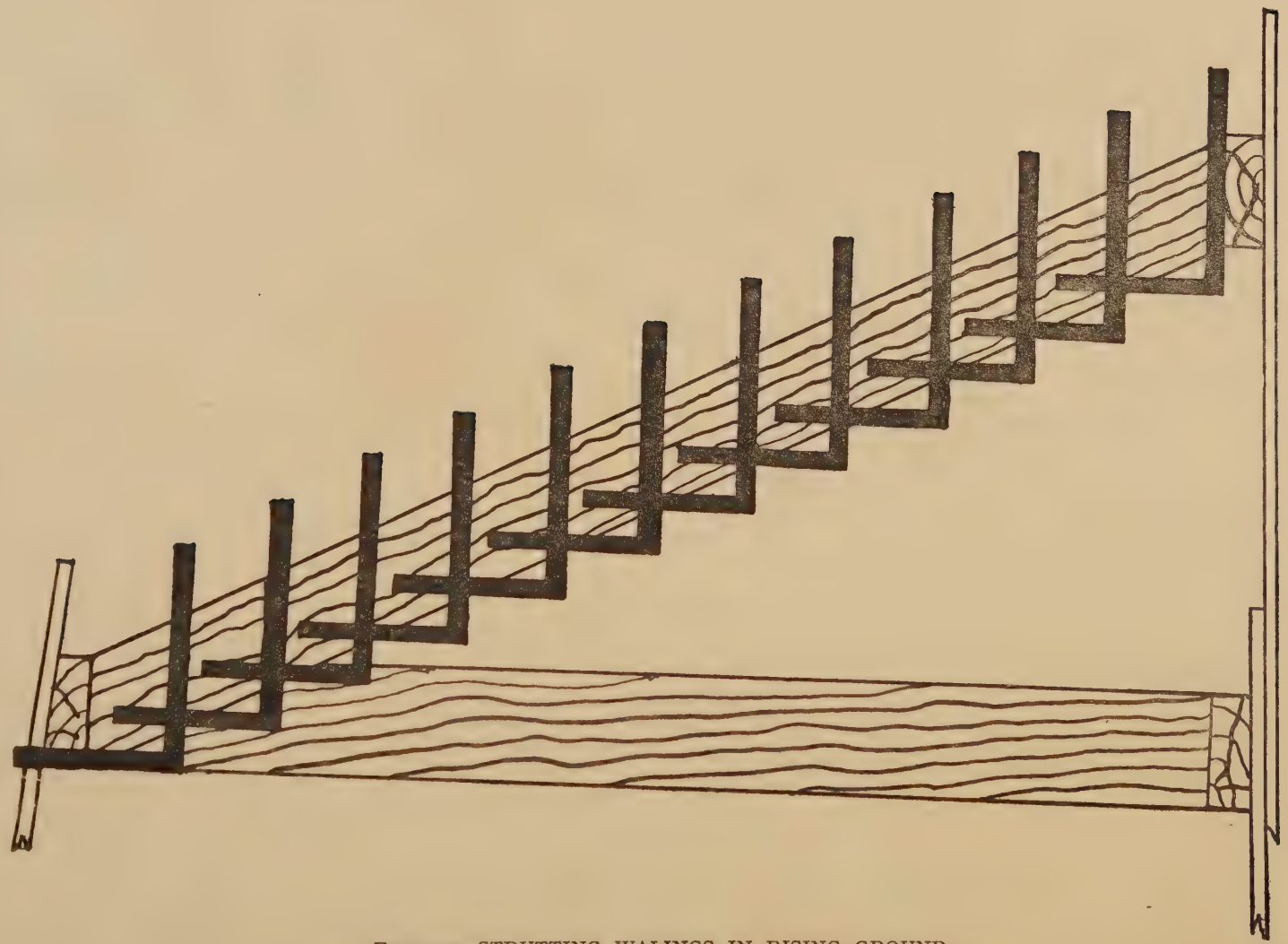


FIG. 250.—STRUTTING WALINGS IN RISING GROUND.
Shows the twelfth-scale figures stepped twelve times to give full-sized results.

frame to the opposite waling of the frame above it. Then the run for the steel square is 10′ and the rise 4′. This pair of figures gives both shoulder cuts. For length we now step the square along one edge of the stuff, setting to 10 on tongue and 4 on blade at every step. Stepping twelve times, we have laid out the full-sized shore. Bracing across between vertical faces, both shoulders will carry the vertical or plumb cut, but the steel-square man with a system will not be puzzled to determine on which arm of his square it can be found. So often as he sets the plumb figures on the blade, he will mark off his plumb cut in the same place.

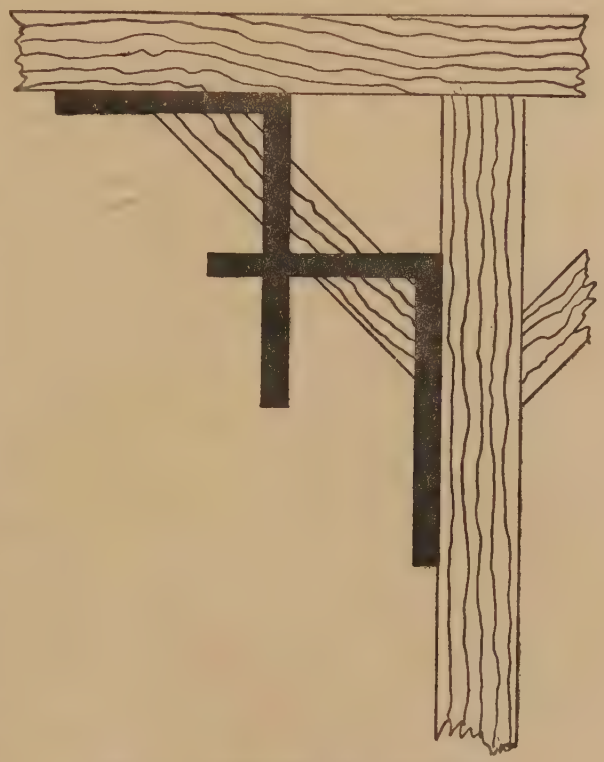


FIG. 251.—SETTING-OUT BRACES.
Shows 1′ rise and 1′ run stepped twice to mark a brace rising 2′ and running 2′.

GANTRY STAGING TO THE FOOT-SPAN METHOD

But a simple braced gantry staging may be called for. All posts and heads are now squared off with the steel square, and only shoulders for the braces are now bevel cuts. Lengths and cuts for large braces may be had instantly as before, by placing their run and rise figures at one-twelfth scale to one edge of the stuff, and either marking and measuring the diagonal for brace length by the first steel-square method, or stepping the cutting figures twelve times up the stuff to obtain brace length by the second steel-square system. Smaller braces, where the run and rise are measured in inches only, will introduce some little difficulty and the third system of steel-square use. In this method the square is used as a full-sized foot rule, and scale measurements are not required. An angle brace for gantry framing is required to rise 2′ and project 2′ from point to point. Plainly at one-twelfth scale these figures will be too small to give our lengths and bevels with any comfort. But if these full-size figures are halved, just as we have already halved the twelfth-scale figures in some instances, we may then take our dimensions to full actual size upon the square, and no longer to the one-twelfth scale. Setting the square to 12″ on tongue and 12″ on blade will

give the shoulder cuts. Ticking distance between these two points direct upon the stuff, we have now marked off length of a brace that rises 12″ and projects or runs 12″. Stepping up the square a second time from these marks, we add another foot of run and rise. Plainly our brace is now correct to bevel, and has the 2′ of rise and run required. A brace that is to rise and run any number of feet whatever can be stepped up the stuff in this manner. But by this third method, it is the foot of span that is stepped up so many times as one foot is contained in the span of the brace that is wanted, and not the twelfth-scale figures that are stepped twelve times to give full-size results, as by the second system.

For braces with an equal run and rise, brace measure, as stamped upon the square and shown in Figs. 237 and 238, becomes of use. This table gives lengths of braces in figures for equal runs and rises, which increase by 3″ steps. For a brace that is to run 3′ and project 3′, brace length is seen from this table to be 50·91″, and we are here in sight of the fourth method of steel-square use, by which lengths are given direct in figures.

But braces may need to stand at many other angles than the simple angle of 45° that is figured for in brace measure. Whatever our brace pitch may be, the square will lay it out. Thus a brace may be needed that is to run 3′ and rise 5′. We divide our pair of figures in equal proportion to get numbers that can be found stamped upon the square. Dividing 3′ by three gives 12″ for use on tongue. Dividing 5′, which is 60″, by three in turn gives 20″ as the blade figure. Then 12 and 20 gives the top and bottom shoulder cuts for this brace, and three steps to these figures gives the full 3′ of run and 5′ rise as called for.

Nothing compels us to regard 12″ as the run figure, and precisely the same results can be obtained when needed by taking 12″ as the rise. Dividing the 5′ of rise by 5 now gives us 12 on the rise side, or blade. Dividing 36″ by the same 5 gives $7\frac{1}{5}$ as run figure for the tongue. Then 12 on blade and $7\frac{1}{5}$ on tongue give exactly the same shoulder cuts as before, while the full brace length is now produced by stepping these figures five times, to get length for 5 times $7\frac{1}{5}$″ or 3′ of span.

Lengths by Figuring

Measuring across the square by the earliest steel-square method, we shall find difficulty in getting lengths that are more accurate than to the nearest half-inch. Stepping twelve times by the second system this inaccuracy will be much reduced. We shall make fewer movements with the square in stepping the foot-span figures, and our lengths are still nearer to final accuracy. Where standard angles have to be repeated, we can get still closer results from figured lengths. Brace measure as given on the square is an example of these standard tables and gives results for the 45° angle. Distance from 12 on tongue to 12 on blade will be found by measurement to be about 17″, but is given more accurately in the steel-square rafter tables as 16·97.″ Then multiplying

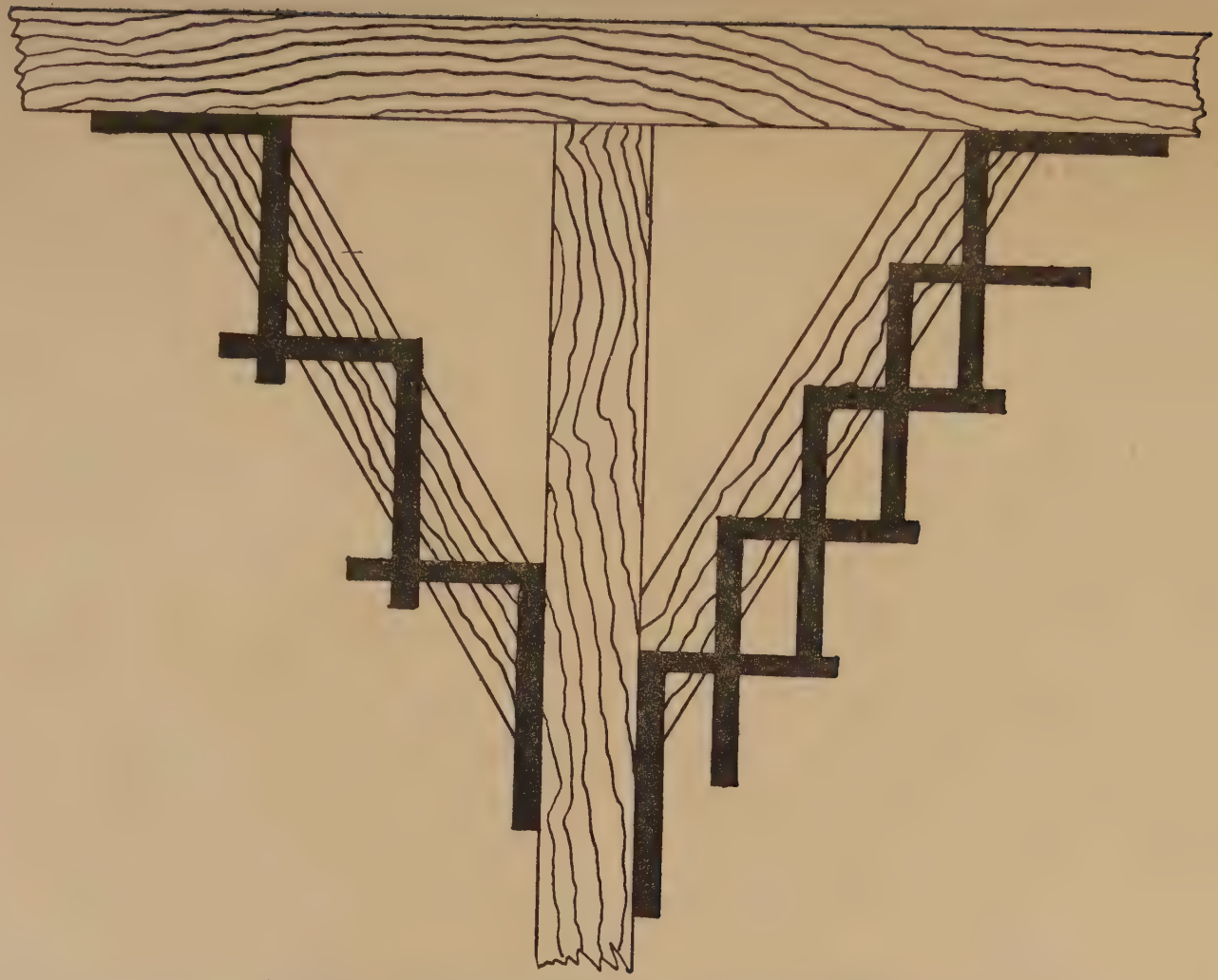


FIG. 252.—A PAIR OF BRACES TO RUN 3′ AND RISE 5′.

Left.—12″ run and 20″ rise stepped 3 times to give 3′ run. *Right.*—$7\frac{1}{5}$″ run and 12″ rise stepped 5 times to give the 5′ rise. Results are identical.

two, three, or more times, according as our brace is to cover two, three, or more feet of span, we shall have constructed a brace measure table that exactly agrees with the figures stamped upon the square. If a 3′ brace for the 45° angle is needed, we multiply 16·97″ by three, getting 50·91″, just as shown in brace measure. With length of the diagonal figured ready for use for the one-foot span, we may get lengths that are correct for any number of feet, or for any fractions of a foot. If a 45° brace is to run and rise by 5′ 6″, then 16·97″ multiplied by 5½ gives 93·33″, or 7′ 9⅓″ as length of the brace required.

Plainly any of these steel-square methods are interchangeable. Thus a length may first be figured to secure accuracy, and then stepped out or measured across the square to check the setting-out and figuring. The shore or brace that has been shown here set out by one steel-square method may be set out or checked for accuracy by another. Stepped or figured methods that have been shown in this chapter supplying lengths for shores or braces, will also give rafter lengths when needed at a later stage.

Some steel-square men will prefer to figure from results that have been stated decimally. Others use ready-figured tables in which lengths are set out for every span and rafter pitch. Still others will establish little simplifications for themselves.

Brace or rafter length for the 45° pitch is roughly 17″, or more accurately 16·97″, for every foot that is spanned by the brace or rafter. But 16·97″ is very close to 1/32″ bare of 17″. Figuring out length for a brace or rafter that is to rise and span 100′ at the 45° pitch, at the 16·97″ figure it amounts to 169·7′. Figuring out again at 1/32″ bare of 17″ we get 1,700 less 100/32″ or 3 1/25th. This is just 1/25th of an inch less in length than before, and shows that even for a rafter spanning 100′ no great error will be incurred in taking either result to figure up from. But stepped lengths can be obtained at any time, while to figure results we must have ready-figured tables available. All methods have been shown here, that the steel-square man may adopt that which seems most suited to his own present circumstances or those of his work.

Concrete Steps and Stairs in Situ

There is another steel-square method that cannot be placed for date, since it is old as the first flight of stairs and modern as the last. It is simply the method by which the steel square is used as a ready-made pitch-board. In this connection the little stair gauges shown in Fig. 244 should be examined. The square is now stepped up the strings to the pitch-board figures. These are not the twelfth-scale figures stepped twelve times to give full-sized results, nor are they the foot-span figures stepped so many times as one foot is contained in the required span. The full-size figures are now rise and going of the stairs, which are divided up into so many full-size runs and rises as serve to produce a satisfactory

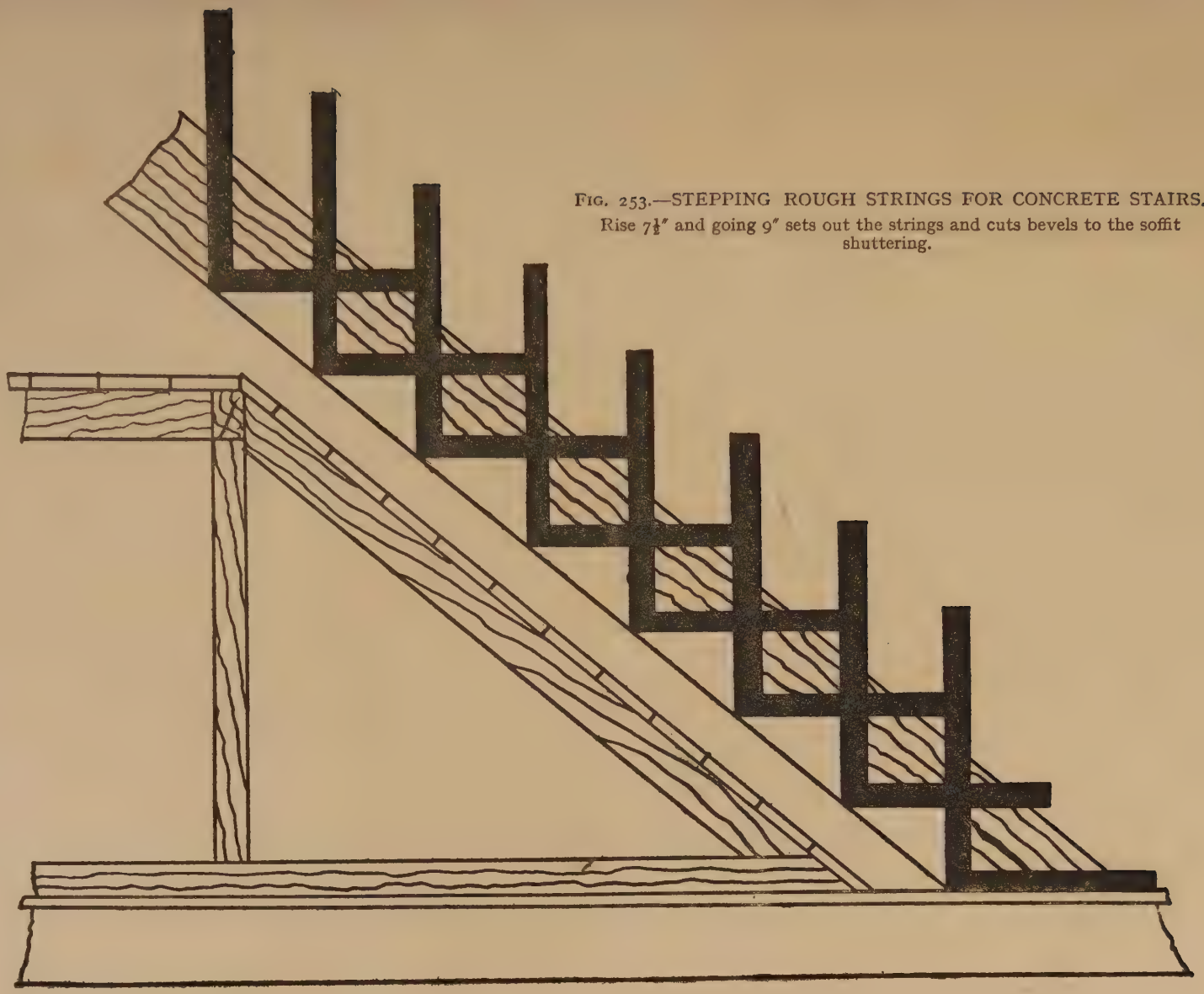


FIG. 253.—STEPPING ROUGH STRINGS FOR CONCRETE STAIRS.
Rise 7½″ and going 9″ sets out the strings and cuts bevels to the soffit shuttering.

tread and riser. Concrete stairs have to be cast *in situ* to the basement. Rise from floor to floor is found to be 8′ 9″, and the architect has shown 14 risers. Then dividing the total rise of 8′ 9″ or 105″ by the 14 steps in which this rise is made, gives $7\frac{1}{2}$″ as the rise of each step, and requires the square to be stepped fourteen times up the string to produce the complete 8′ 9″ of rise. Sometimes the going will be figured in or specified. In other cases it must be determined from the space available in the well. Thus in our 3′ basement flight the architect has shown two quarter-space landings and seven treads, spaced into a well that measures 11′ 3″. Deducting 6′ for the two quarter-space landings leaves 5′ 3″ or 63″ for the seven treads, equalling 9″ for each. Then with $7\frac{1}{2}$″ on blade and 9″ on tongue we set out our rough strings as shown in Fig. 253. Passing them to the saw we cut out these strings, and the cuttings that come out will be nailed to a length of 4″ by 2″ to form a central support against pressure of the concrete. With pitch figures for these stairs known, the soffit shuttering can be cut and set up first to this angle.

CHAPTER XI

STEEL-SQUARE CARPENTRY FOR THE BRICKLAYER

By Harold Ryder

Turning-pieces and Segmental Centres—Finding the Radius Mentally—Mitreing Up Segmental Centres—Segmental-gauged Arches—Flat-gauged Arch Moulds—Semi-circular Centres and Circular Drums—Bay Moulds and Squint Moulds—Building-in Stone Steps—Straight Centres for Flues.

Turning-pieces and Segmental Centres

One of the earliest items to be put in hand for the bricklayer will be the forms upon which he must turn his arches, whether flat or cambered turning-pieces, segmental centres, semi-centres or complete circular drums. Flat or cambered turning-pieces will usually be cut from the solid upon the saw-rig, and will call for no construction. Cambered or segmental centres present a simple little steel-square solution. Usually the architect will either specify his segmental heads to rise by one definite amount in every foot of width, or he will leave the steel-square man free to adopt any suitable standard figure.

There are several more or less elaborate rules for calculating lengths of the radius rods for various spans and rises, but the steel-square man who works to the foot-span method will simplify his operations till he can produce any necessary radius mentally. Where these segmental heads are to rise one inch in each and every foot of span, then the radius is known to be always $18\frac{1}{2}''$ for every foot of arch span. A centre of this type is to span 2′ and rise 2″. Without calculation its radius is known to be twice $18\frac{1}{2}''$, or 3′ 1″. A wider centre of the same type must span 4′ and rise 4″. The length of its radius rod is known instantly as four times $18\frac{1}{2}''$, or 6′ 2″. Another centre of this type that spans 5′ 6″ and rises $5\frac{1}{2}''$ has its radius rod cut to $5\frac{1}{2}$ times $18\frac{1}{2}''$, or 7′ $8\frac{1}{2}''$. There is no quicker or more reliable method. Cutting the ribs by hand, we shall need to strike and rip each rib separately. Cutting on the saw-rig we brad two radius rods to the table at the given distance from the saw teeth, and we sweep out all ribs in succession to the one curve.

But having systematised his segmental centres for his own purposes, the steel-square man will find that he has conferred another benefit upon the bricklayer. All the angles of these arches are alike, and the bricklayer will find that he can now cut every skew-back to one and the same standard bevel. A gunstock profile is cut for this series of arches, and each and every segmental skew-back or abutment can be cut to it.

For the steel-square bevel which will cut this profile we subtract the 1″ rise from the 18½″ radius, getting 17½″ as blade figure, while 6″ is used on tongue.

A centre of different proportion may be preferred, but the method still holds good. Perhaps all segmental arches are now to rise 1½″ for each and every foot of span. By the foot-span method the radius of these centres is 12¾″ for every foot that the centre is required to span. The centre that is to span 4′ has a rise of 4 times 1½″ or 6″, and its radius rod is 4 times 12¾″ or 4′ 3″. For steel-square figures for the skew-backs we subtract the 1½″ rise from the 12¾″ radius getting 11¾″ and 6″ as figures for use upon the square.

Still other rises may be selected, and the method is still available. Where these segmental heads are to rise 2″ to the foot of span, then the radius is 10″ for each and every foot of span. The 6′ centre now rises 6 times 2″, or 1′, and has a radius of 6 times 10″, or 5′. Again the abutment or skew-back angle is had by subtracting the 2″ rise from the 10″ radius, getting 8 and 6 as steel-square figures for the skew-back profile. If some other rise should be selected, the methods are the same. With figures found for the centre which is to span one foot, radius lengths and skew-back angles can be produced from memory for centres of any span whatever. Skew-backs to a wide and narrow arch may chance to stand back-to-back upon the same pier, but the skew-back angles for all arches are identical, and each arch penetrates the pier to the same standard depth.

Mitreing Up Segmental Centres

With large spans we shall need to mitre up the ribs like a pair of rafters to form one large centre. Plainly the rise and run figures of any rib will provide both seat and mitre cuts. All the centres that rise 2″ in 2′ are cut to the soles and mitred at the centre with 2 and 12 upon the steel square. Any rib that rises 3″ in 2′ will be mitred together at the middle with 3 and 12. All segmental centres that rise 4″ in 2′ have their plumb and seat cuts given by 4 and 12, and so for segmental heads of any other rise.

Segmental-gauged Arches

Where gauged brick arches are employed, still more preparation falls upon the carpenter before the bricklayer can be put to work with any safety. He first sets out width of the arched opening upon a planed-up board, and next marks in his standard skew-backs with the steel square. With the radius rod he sweeps out soffit line of the arch, and extending the rod he puts in the back of the arch from the original striking point. He has now the outline of a full-sized drawing of this arch for the bricklayer. But he will next be required to show all joints to the arch. He

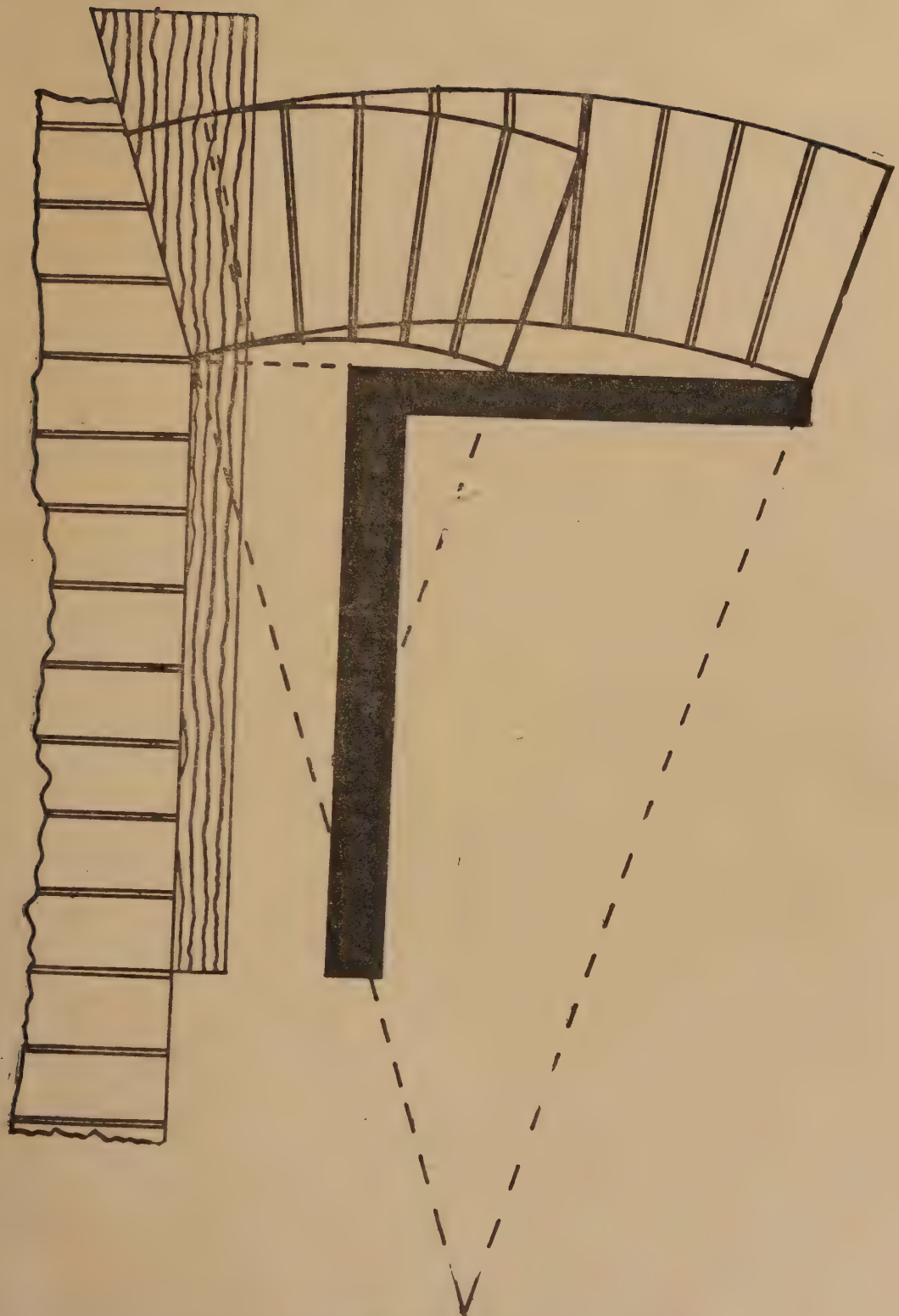


FIG. 254.—RADIUS RODS FOR CAMBERED ARCHES CAN BE FIGURED MENTALLY, AND EVERY SKEW-BACK CUT TO ONE TEMPLATE.

will find that standard rubbing bricks for gauged arches are much larger than the bricks that are used for face work, and if permissible an arch brick larger by three-quarters of an inch could be cut from them. But the architect may be expected to object if given two sizes of brick to arches and straight walling, and the carpenter must restrict himself to standard brick sizes in getting out his arch moulds. Three inches may well be taken as the maximum width of red rubbers, and for preference they should match the standard face work as closely as width of the given arch will allow. Generally an architect will object to finding a vertical joint on centre line of the arch, and will call for a solid brick in this position. For first shot $1\frac{1}{2}''$ may be measured off to either side of the centre line on back of the arch, to show width of the centre arch brick, and the spacing can be run out at the same 3″ to find number of bricks that must be employed. If this 3″ spacing should end directly on the skew-back line, joint lines may be ruled in to all these spacings with the radius rod. Should the last space fall out beyond this skew-back, then this excess must be divided equally among all spacings, till the arch passes from skew-back to skew-back in an odd number of arch bricks all uniform in size. These joints are marked out upon the board, and a pair of cutting templates are got out from $\frac{1}{2}''$ or $\frac{3}{8}''$ stuff for use of the bricklayer. Next the carpenter will make him a cutting box, either nailed together as a temporary measure to cut a single arch, or more elaborately constructed to be adjustable for any arch brick angle that is needed. A box to cut one arch will not require shoeing, but a more permanent tool is best faced upon its upper surface with $\frac{1}{4}''$ bar, which will prevent the bricklayer's saw of twisted wire from jagging the edges and destroying its accuracy.

Flat-gauged Arch Moulds

When frames were invariably set back in $4\frac{1}{2}''$ or 9″ reveals, the flat-gauged arches to these openings were usually specified to rise $\frac{1}{8}''$ in every foot of span, on the ground that the eye would assume a sag in soffits left perfectly straight. To-day most straight arches rest directly on frames set flush with the face work. A camber is therefore impossible, but the eye accepts the underlying frame head as straight, and no camber is really called for. With these flat-gauged arches the carpenter again supplies accuracy while the bricklayer provides energy. On a planed board the carpenter sets off the width of his opening, and puts in his standard steel-square skew-backs at these points. He marks off upper and under sides of the arch, which he may call the extrados and intrados, if the architect is listening. He next indicates drop of the keystone if one is shown by the architect. Again a solid centre brick will be placed on centre of the arch, to meet the architect's probable objection to a central joint. An experimental arch brick is laid out, and a pair of templates are got out to this pattern. Keeping both in turn to the

soffit or intrados line, these two templates are stepped across the arch, one following tightly to the other, till the arch is crossed from skew-back to skew-back. At the far side the result is noted. If the last template is correct to skew-back angle but incorrect as to position, the pair of templates have either to be brought down or lifted up in the arch. If, as is probable, the last position of these templates falls out of parallel with the further skew-back, both templates have now to be corrected together till they can be stepped across the arch from one skew-back to the other. With the correct angles obtained, both templates are now lined across and adjusted for depth, when they are stepped across for the last time and all joint lines are put in upon the board. Cutting boxes will be needed for temporary use, or, if a permanent box has already been provided, the bricklayer himself will be able to adjust this to the templates provided.

Semi-circular Centres

Where complete bull's-eye drums or semi-circular centres are needed, length of the radius rod is had direct from width of the opening. Half of this distance is radius of the brick arch and outer face of the laggings. Deducting thickness of these laggings, we have radius for cutting the ribs. The cuts that will mitre up these separate ribs correct to curve will also be needed. The beginner will sometimes turn out centres with little pieces patched into their curves at unexpected places, but a better impression will be given if the curve is carried on a number of ribs all equal in length. A small centre may go right around its circle in four pieces, or around the semi-circle in two. Plainly these ribs will cut to the sole pieces and the mitre at the true mitre or angle of 45°, so 12 on tongue and 12 on blade will give these cuts. Completing the circle in four pieces, plainly these four pieces make a square. But if we should choose to complete the same circle in any other number of equal pieces, just as certainly we can mitre up the drum as a polygon with the given number of sides. A use is found at once for the table of Polygon Mitres that is stamped on different makes of squares. If five ribs are to mitre up a complete circular drum, plainly the figure is a five-sided or pentagonal polygon, and the pentagon mitre, 24 and 17 5/12ths, cuts its joints. Three equal ribs in the semi-centre or six in the full circular drum shows the six-sided or hexagon mitre, which is cut by 24 and 13 10/12ths. Eight ribs to the drum or four to the semi-centre employ the octagon mitre, 24 and 9 11/12ths, or roughly 12 and 5, to joint them up, and so with all other polygons. Every square has its own way of stating these angles, but the results agree. Some squares give the octagon mitre as 24 and 10. Others employ 18 and $7\frac{1}{2}$. Plainly all three angles are alike, and it is simply a matter of convenience which we select for use. More use will be found for the polygon mitres on horizontal moulds, and a table for mitreing any polygon having up to 32 sides now follows. The triangle

is not shown in this table, but its mitre is found upon the tongue when the square is set for marking hexagon mitres on the blade.

Table of Halvings and Mitres for Polygons

To halve or mitre any polygon, on blade use 24, and on tongue the figure found in this table standing against the required number of sides. Halvings are all marked off along blade, and mitres by the tongue.

Mitre for	Inches.	Halving for	Mitre for	Inches.	Halving for	Mitre for	Inches.	Halving for
5 Sides	17 5/12	10 Sides	14 Sides	5 6/12	28 Sides	23 Sides	3 4/12	46 Sides
6 „	13 10/12	12 „	15 „	5 1/12	30 „	24 „	3 2/12	48 „
7 „	11 7/12	14 „	16 „	4 9/12	32 „	25 „	3	50 „
8 „	9 11/12	16 „	17 „	4 6/12	34 „	26 „	2 11/12	52 „
9 „	8 9/12	18 „	18 „	4 3/12	36 „	27 „	2 10/12	54 „
10 „	7 9/12	20 „	19 „	4	38 „	28 „	2 8/12	56 „
11 „	7 1/12	22 „	20 „	3 10/12	40 „	29 „	2 7/12	58 „
12 „	6 5/12	24 „	21 „	3 8/12	42 „	30 „	2 6/12	60 „
13 „	5 11/12	26 „	22 „	3 6/12	44 „	32 „	2 4/12	64 „

Bay Moulds and Squint Moulds

Just as the polygon cuts will mitre up vertical timbers for drums or centres, so straight or circular horizontal moulds may also be cut with them. If wings of a bay are to stand at the 45° angle, carried right around the circle this figure would form a complete octagon, so octagon mitre, 12 and 5, lays off mitre cuts for the bay mould. In due course all moulding mitred around this bay, such as picture-rail, cornice, window-board or skirting will be mitred up correctly with the same pair of figures. Perhaps special squint bricks are to be axed off and rubbed up upon the job to secure a colour match and avoid delay, and the bricklayer will then require a squint mould to this angle. With size of a standard brick and the 45° mitre, the carpenter sets out his squint moulds as in Fig. 255.

Many architects will prefer to employ the cant that has wings standing at an angle of 60° with its face line. Completing this figure around the circle, we see that it is simply one portion of a hexagon, so the hexagon figures will set out the bay mould now, and in due course will cut in all mouldings running round these bays. A device such as shown in Fig. 255 will eliminate all special cutting upon squint angles, but if special squints are to be cut and rubbed upon the job, the same hexagon figures will allow the carpenter to lay out his squint moulds correct to angle.

Oriel frames may have been designed to run around the circle in 12, 16, or more sides, but the appropriate figures from the table will first mitre up the mould that is needed by the bricklayer, and in due time will cut all finishing that fixes in or around these frames.

On similar lines to an oriel, straight single lights are sometimes assembled around the circular curve, to give a frame that will stand upon circular brickwork, and will resemble the old and costly circular bay

window. With the number of sides known in which the full circle is completed, all mitre cuts for present and future needs are available as before.

Straight walling is built to the line, but all circular sweeps are put in to moulds prepared by the carpenter. Where the curve is large, a big sweep may be mitred up for the original setting-out and for occasional checks, together with smaller sections of the same curve for carrying on meanwhile. With the portion of the curve that is to be covered and the number of ribs that must be employed, the number of pieces that

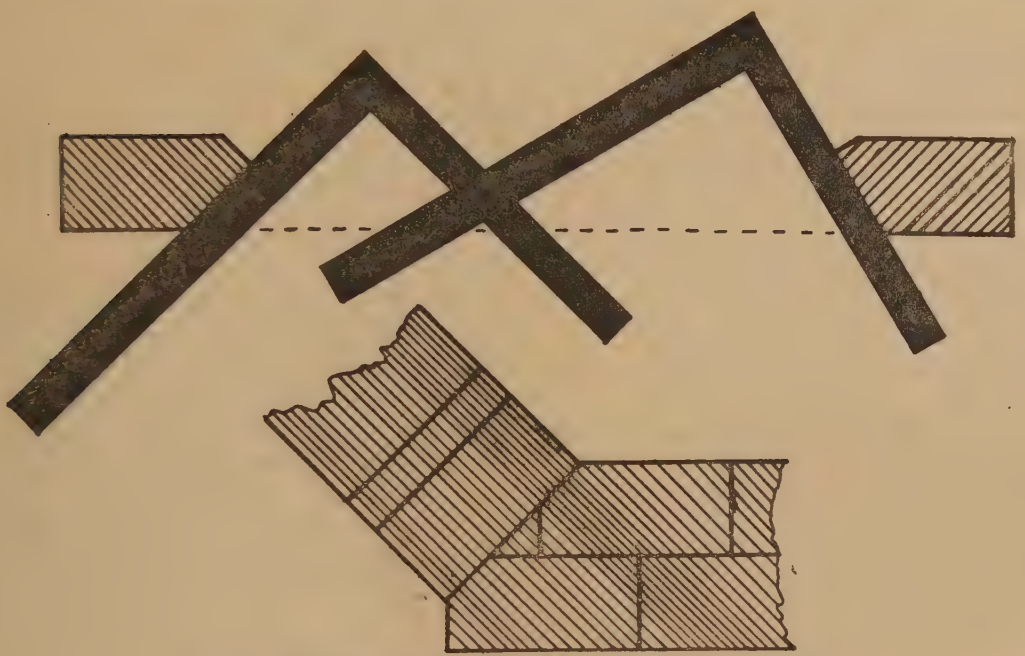


FIG. 255.—SQUINT MOULDS WITH THE STEEL SQUARE.

Upper line, left.—12 and 12 cuts moulds for an octagon bay.
Upper line, right.—12 and 20¾ cuts moulds for the hexagonal bay. Lower line shows how a 2¼" nib avoids the use of squint bricks.

would appear in the full circle is known, and the appropriate mitre taken from the table.

BUILDING-IN STONE STEPS

Where stone or concrete steps build-in between two solid walls, the bricklayer will be found capable of conducting the operation for himself. But if one end of each step is to remain without support to form an open well, then the carpenter will be called upon to provide a temporary support for the free end of every step.

A sill, a raker and one or more studs or raking struts will be required. All must be cut to the stair pitch, and this pitch is found immediately

by measuring the treads and rises that have been given to the steps supplied. Used upon the steel square, this rise and going first cuts the raker down to bed upon the sill, marking on the side that carries the horizontal or going measurement, since it is a level cut that we require. Plumb supports or pitched rakers can be used. If uprights are inserted as the work mounts upwards, since they are vertical timbers, their cutting bevels are marked upon the square on the arm where the vertical or rise figure has been set. Struts pitched to stand square off the raker may be preferred. The cut to the raker is now square, and their sill cuts are square from sill cut of the raker, so again are marked with the rise figure. Where the bricklayer can be relied upon to build correctly to the given pitch, the main raker can be placed flat to soffits of the steps, and every fresh step then beds flat upon it. With variable steps or a variable bricklayer, the raker is best packed down from this soffit, by some definite distance, such as 2″. A 2″ pair of folding wedges then provide the necessary adjustment to every step.

Straight Centres for Flues

Reaching plate levels the bricklayer will require to gather in his flues to central stacks, and will call for straight centres upon which he can rack his brickwork over. He will have most respect for the carpenter who can set these up so that his brickwork comes over without any cutting at regular bond. In the 3″ course customary in the south, working quarter-bond every brick will come over $2\frac{1}{4}$″. These are accurate but inconvenient figures for use upon the square, and may be increased to 12 on tongue and 16 on blade, which are an exact equivalent. The diagonal distance between these points can be shown to be exactly 20″. Then if a distance of 10′ is found by measurement to exist between two chimney breasts which must meet in a common stack, we know that our two straight centres must each cover 5′ of this span. Then the span for each is 5′, the rise of each is 5 times 16″ or 6′ 8″, and the length of each timber is 5 times 20″ or 8′ 4″. The plumb and seat bevels that cut these rakers are 12 on tongue and 16 on blade. Marking and cutting we pitch the pair of centres, and the bricklayer in good time discovers that his stack comes over in regular bond without cutting bricks.

Where due cause exists, we may bring these stacks over at half-bond, equalling half a brick or $4\frac{1}{2}$″ at every 3″ course. It is not necessary to say that this rake is much flatter than is fair to the flues, but sometimes the architect has provided no greater roof space, and the flues must be got over at this rake if they are not to project outside. Once more $4\frac{1}{2}$″ on tongue and 3″ on blade will give these cuts, but 12 and 8 will duplicate this angle exactly, and are more convenient for use upon the square. Diagonal distance between these two points is found to be 14 5/12ths. Between the same two chimney breasts 10′ apart we now propose to set up a pair of straight centres on which the bricklayer can gather over

at half-bond without cutting. Each centre now rises 5 times 8″, or 3′ 4″. Each centre is 5 times 14 5/12ths or 6′ $0\frac{1}{12}$″ in length. Plumb and seat cuts are supplied by 12 on tongue and 8 on blade. Where bricks vary in dimensions and make four courses to the foot impossible, suitable cutting figures for these straight centres can still be had with ease. Dutch facings may be employed which lay $2\frac{1}{2}$″ courses. Setting over in quarter-bond at $2\frac{1}{4}$″ in $2\frac{1}{2}$″, we have correct but inconvenient figures for the square. Increasing each side four times, we get 9 and 10 in even figures, or can increase both sides by one-third to obtain 12 and 13 1/3rd if desired. These are cutting figures for the straight centres giving quarter-bond in these special bricks, and in place of figuring for lengths we may step the square five times up the stuff to these figures. Half-bond would come over at $4\frac{1}{2}$″ in $2\frac{1}{2}$″, which is altogether too flat to be admissible.

Foundry bricks may be employed in the north, going perhaps 14″ to four courses, or $3\frac{1}{2}$″ at every course. Then at quarter-bond we shall now set over $2\frac{1}{4}$″ in each $3\frac{1}{2}$″ course, or 9″ in 14″, which once more is 12″ in 18 2/3rds.

No matter what courses the bricklayer may require to work, with the steel square you can cut his straight centres in advance, on which every stack can be gathered over without cutting and without breaking bond.

CHAPTER XII

CARCASSING AND FIXING WITH THE STEEL SQUARE

By Harold Ryder

Square-angled Trimming—Octagonal Trimming—Herring-bone Strutting—Trimming to Bay-windows—Stud Partitions—Stair Fixing.

Square-angled Trimming

Set for bevelled work to any two given figures, the steel square will measure off a pair of bevels each standing accurately square with its neighbour. Set to a single figure only, the steel square then measures off a length along the stuff and sets in a square cut at this measured distance. We are tusk-tenoning our trimming, and require some cross trimmers set out to 4′ 6″ shoulders. Every man will have slight individual variations in the measurements to which he sets out his trimming, but the general procedure will be alike with all. We start setting out at either end of the stuff, for the square will work equally well in either direction. From end of the timber we measure off 8″ for length of the tenon, with the 8″ figure that stands upon inner edge of the tongue. At this point we square a line across. From this haunching line we advance another 5/8ths to the shoulder line, and square across again. Setting 12″ on inner edge of the tongue to this last line, we mark along both sides of the blade for our first mortise. Setting 12″ again to the last of these lines, we mark along both edges of the blade for position of our second mortise. Setting 12″ once more to the last mark of this pair, we mark in the third mortise. For the last time we set to 12″, and at this point put in the 4′ 6″ shoulder line. From this we advance 5/8ths again for the haunching. Setting 8″ for tenon length to this haunching line, we measure off tenon length and have completed our spacing. If desired, other trimmers can be squared off from the first one, but the steel square sets out so rapidly that the same time will be expended in copying off the old marks as in placing fresh lines entirely.

Octagonal Trimming

And what has been done so easily on square trimming is performed with equal ease on angle work. Perhaps the architect has designed a " sun-trap " residence on the lines of a giant bay-window. Both wings will stand at the angle of 45° with line of the centre portion. In the well-hole a trimmer stands upon the mitre-line of this building and

receives heading joists that are tenoned into it on both faces. Every repetition of all standard bevels is alike, and we know that octagon mitre will be the same whether used to mitre up little picture-rails or a

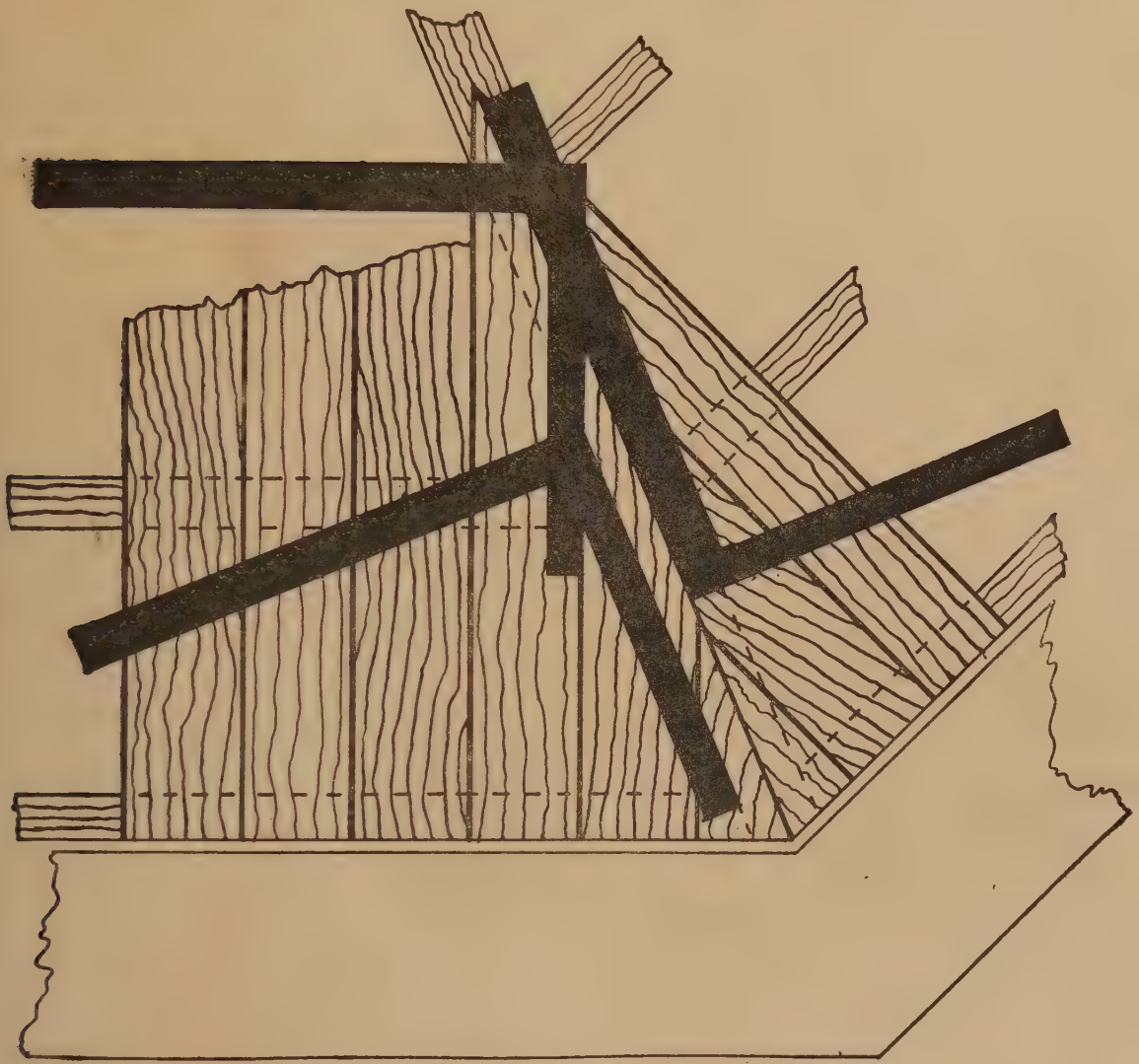


FIG. 256.—JOISTING IN THE OCTAGONAL BUILDING.

Octagon mitre, 12 and 5, sets out mortises on the trimmer, shoulders to the joists, and mitres up the floorboards.

substantial building. Then octagon mitre, 12 and 5, sets out all mortises and cuts the shoulder-lines to all the trimming. Marking along both edges of the blade when set to the 12 and 5 that are found along the inner edges of the square, at the same instant spaces in our heading joists upon the trimmer and sets out the mortises correct to bevel as

seen in Fig. 256. Later on this upstairs landing will require flooring. Joists and floorboards stand at square angles with each other, so the same figures that now give shoulders to the heading joists when marked on the 5 side, will afterwards supply mitre-cuts for the floorboards when marked along the arm where 12 is set.

An angle fireplace stands across one corner of a bedroom at the true mitre angle. This 45° bevel is set out with 12 and 12 on every occasion that it turns up, whether it is required for cutting architrave mould or mortising angle trimmers and setting out the joists. Mortises are now spaced out along the trimmer with these figures. The same pair of figures will set out the mortise bevels, and shoulders to the heading joists are set out with them too. Fresh angles may crop up in joisting, but every one can be read off in steel-square figures, either by applying the square directly to the drawings or by laying it down upon existing work. Once a bevel has been turned into figures for the steel square, whether old familiar friends or novel faces, these figures may be carried away to the timber stack and marked off accurately for use.

Herring-bone Strutting

Any known pair of figures will fix accurate cutting bevels upon the steel square, and will also supply lengths for the timber that has to be cut. Depth of our joists is known, and their spacings may be standardised, or if different can all be measured. With depth and spacing figures the steel square will set out the herring-bone bridging correct to lengths and angles. Depth of joist is of course equivalent to depth of the bridging measured from its upper to its under edge, and the steel square must be placed upon the material to produce this measurement correctly. The depth figure is used upon blade and goes to further edge of our bridging stuff, keeping the bridging within the specified depth of joist. If by mistake both figures should be placed to one edge, the whole depth of one bevel will stand above or below the joist levels. Setting the square correctly, we mark along the arm by the figure showing depth of joist, since it is a vertical figure and it is the vertical cut that we want. We tick upon the opposite arm where joist spacing has been set to mark off the length, and slide the square along until the vertical bevel reaches this point. Here we put in a second vertical cut, and repeat the whole operation for the second piece of bridging that is needed for the same opening.

Trimming to Bay-windows

Some hexagonal-angled or 60° bays are roofed with lead flats, on which the architect has called for a substantial fall finishing at a projecting box cornice. We therefore place a solid joist upon the mitre line to receive the mitred ends of the cornice and boarding. Every hexagon angle is known to be cut with 12 and 6 11/12ths, so we cut

our angle joist to fit against the wall trimmer and mitre up all the roof boarding to the one standard bevel. On front face and wings a single short joist is to bevel against side of the hip joist. Again the hexagon figures mark its cut, but this time marked by the sharp bevel found where we set to 12. Short joists also run in from the wings to the wall trimmer. This cut only duplicates the cut of the short hip joists, and the same figures set out their bevels.

With the lead boarding mitred up to hip lines and to walls with the same figures, in due time the same figures mitre up the flat cornice soffit boards, and cut the mitres to its vertical fascia. With the same standard figures we prepare the mitre box in which the small cornice mouldings will be cut.

Bay-windows may be carried through two floors, but once their angles have been read off, they can be quickly duplicated for any purposes. Plates or heads may be needed for the studding which is to carry an upper bay upon one set beneath it. Plates for every octagon bay on any building are always halved together with 12 and 12, or mitred up with 12 and 5. To secure greater accuracy and a wider bevel, we may double these figures if desired, and take them, as shown in the table given for polygon mitres, to be 24 and 9 11/12ths. All 60° or hexagonal bays are both mitred and halved together with the one pair of figures, 12 and 6 11/12ths. We may take these doubled from the polygon table as 24 and 13 10/12ths. All through the job the angles of these bays will remain known, and every moulding that must be carried around their inside or outside faces can be mitred up with accuracy at first cut.

Where flooring is carried out into the bays, the standard cutting figures still hold good. The cut is found on one arm or other of the square, according as the flooring is laid directly into or across the bay. First fixing brings window boards and nosings to these bays, and the same standard figures supply their mitres without hesitation and without experiment. Second fixing calls for skirting and architraves to be carried around these bays, but every cut is known in advance and is laid out and made in a moment.

Stud Partitions

Heads and sills are set out and spaced in with the steel square, exactly as was done with square-angled trimming. The 2″ blade marks both sides of the stud mortises at a single setting. Figures found set along the inner edge of tongue will measure off the distances between these studs. Brace bevels for stud partitions are had by any of the steel-square methods which give lengths and bevels for any other brace. Length of the studs will supply the rise between head and sill, and gives the rise figure for the steel square. Run of the individual braces can be measured off between studs, and forms the second steel-square figure. With rise and run of these braces known, we have plumb and seat cuts both for the

braces and for any horizontal noggings or vertical studs that cut against them. Lengths of the braces can be had by the twelfth-scale method, by stepping the square, or by figures. If a single partition is to be fixed as it is cut, time and trouble may be saved if we mark either head or foot of the brace with the rise and run figures. Cutting one end, we may place the other to position and mark off in place.

Stair Fixing

Staircase winders introduce fresh material, but nothing new in figures. Not long since two winders in the quarter-space was an unheard-of piece of planning. So soon as we meet this unfamiliar arrangement, the cuts will be seen to be very familiar figures on the square, for 12 and 12 supplies them all. Two winders in the quarter-space amounts to four winders in the half-space, and we cut them with the halving cuts for a four-sided figure. Three winders to the quarter-space is a more usual arrangement, and the cutting figures for all these winders are very old friends. Three winders to the quarter-space equals six winders in the half-space, and we mark their cuts with hexagon halving figures, 24 and 13 10/12ths.

Occasionally an architect will distribute five winders around the space that might have been occupied by a half-space landing. We take out their cuts from the table as if they were halvings to a five-sided figure. Any other number of winders may be arranged within the half or quarter space. Seven winders within the half-space will be cut as if they made up a seven-sided polygon, and so for any other number of winders that may be met with. In turn all under-carriaging to these winders will be cut with the same figures that have already cut their winders. Measuring the rise and going of one step, we have figures which cut all timbers to fit the stairs. Carriages below the straight flights will be cut with them, using rise or going figures to mark by, according as to whether the timber is to be plumb or level. Studs may stand below these carriages and form the rear of an under-stair cupboard. Rise and going figures are both needed to set this bevel, but it is the vertical or rise figure that we mark by. A horizontal false ceiling cuts in below the straight carriages, and closes off the winders in a level ceiling. The same pair of figures will supply this bevel, but marked by the level or going figure, since these are level timbers.

If shoulders to the stair strings need truing up before fixing newels, the same rise and run figures give an accurate shoulder bevel. These figures, if small, can be doubled or even trebled to obtain a bevel which will mark right across the material. Handrail shoulders are set out direct with the same pair of figures, or a mitre-cut can be constructed with them in which their shoulders can be cut.

CHAPTER XIII

STEEL-SQUARE ROOFWORK

By Harold Ryder

Pattern Rafters to Twelfth-scale Figures—Patterns by Stepped Figures—Rafter Lengths from Ready-figured Tables—Setting-out Hips and Valleys to Twelfth-scale Figures—Stepping Hips and Valleys—Lengths from Hip and Valley Tables—Purlin Cuts.

Every bevel throughout the building calls for steel-square solution, but probably the majority of all steel-square men bought their squares in the first place especially to cover roofing. There is no better equipment. Every steel-square method that has been shown in this section can be applied to roofwork, beginning with the twelfth-scale system, passing through the several methods for stepping the square, and ending with figured lengths derived from tables. Like every other raker, the rafter will be cut correctly to length and bevels with its rise and run figures. This rise and run must first be found from the architect's drawings, and once discovered every other cut about the roof is also known. But the roof pitch is known so soon as it has been laid out by the architect, and if desired all roof timbers may be cut in advance of the brickwork. When the bricklayer arrives at plate levels the whole roof is ready for immediate erection, and delays due to necessity for cutting the roof in place are removed.

Brickwork sizes across the building will be found figured in upon the architect's drawing, and if required may also be checked by a measurement upon the actual brickwork. Very rarely, upon small sheds, $4\frac{1}{2}''$ plates may be found setting directly upon the top of $4\frac{1}{2}''$ brickwork. Here the figured distance across the brickwork will be identical with the distance over plates. In most cases the plate will be less in width than the walling, and will usually set flush with inside face of the brickwork. Then plates will now be set back from outer faces of both walls, and the measurement across both plates will be less than the figured brickwork dimensions. With measurements across the outer walls discovered, we have next to find the distance across both plates. Plainly this measurement will be spanned by two rafters and the central ridge. From distance across plates we deduct ridge thickness, which leaves us with the span of two rafters. Halving this distance gives us the span figure required for use upon the square. In the roof illustrated in Fig. 257 overall brickwork sizes are found to be $18'\ 11\frac{1}{2}''$, and the $4''$ by $3''$ plates to fall flush inside will set in $5''$ on each wall, or $10''$ together. Overall

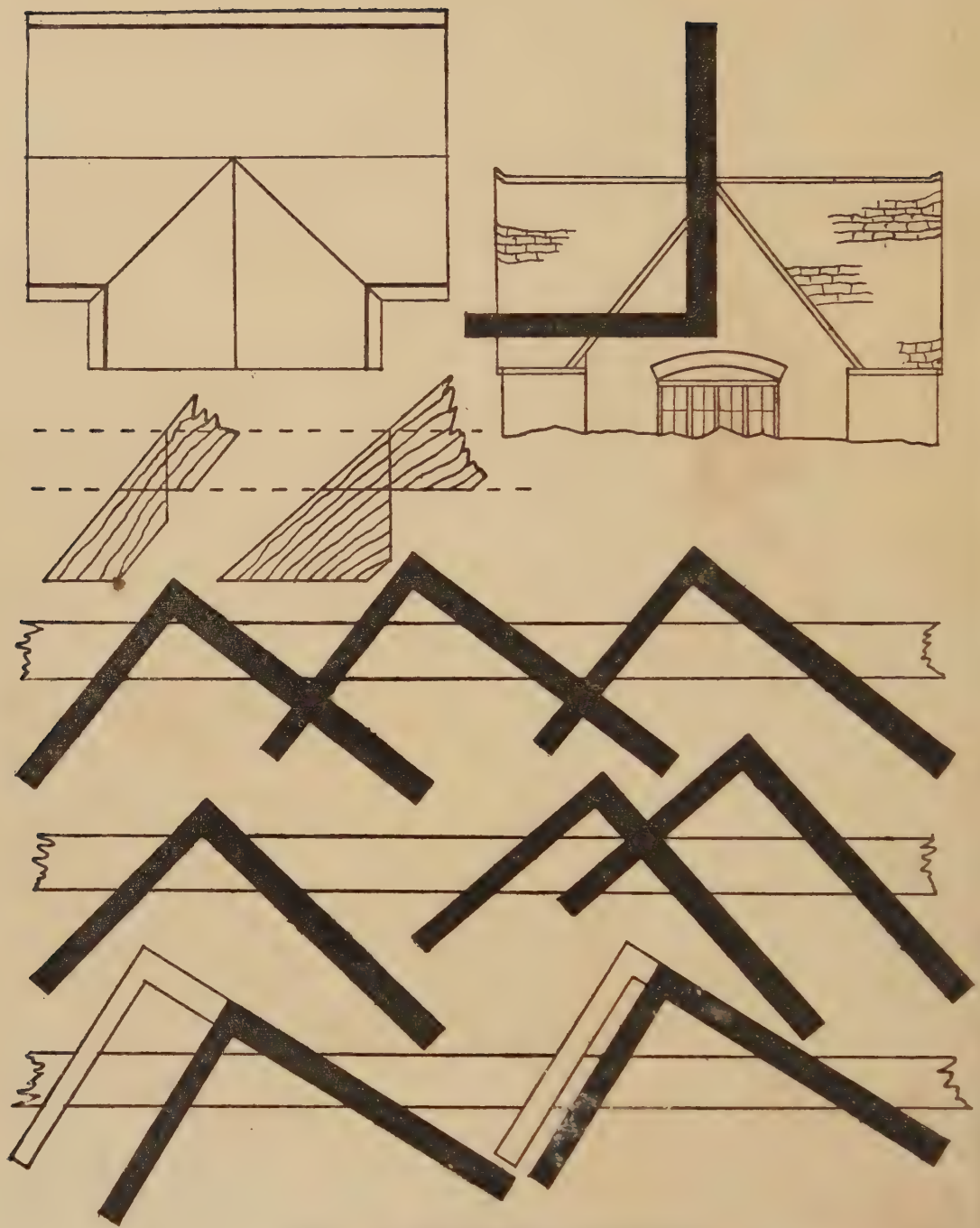


FIG. 257.—EVEN-PITCHED ROOFWORK.

Upper line.—(1) A roof measuring 18′ 11½″ over plates has each rafter spanning 9′. (2) In this span the rafter rises 11′ 3″.

Second line.—Give all rafters, jacks, hips and valleys the same plumb backing.

Third line.—(1) 9′ and 11′ 3″ marks rafter cuts. Distance measured between these points, 14′ 5″ is rafter length. (2) Rafter length 14′ 5″ and rise 11′ 3″ gives side cuts for lying purlins. (3) 12 and 15 gives the same rafter cuts to foot-span figures.

Fourth line.—(1) Diagonal of the 9′ rafter run is read off as 12′ 9″ hip run. (2) 12′ 9″ hip run and 11′ 3″ rise gives lengths and cuts for hips and valleys. (3) 17 and 15 gives the same hip and valley cuts to foot-span figures.

Fifth line.—Run 9′ and rise 11′ 3″ gives side cuts for jack splays. Run 9′ and rafter length 14′ 5″ cuts jack splays and top purlin mitres. Slid to show jack spacing on tongue, the square reads jack variation on blade. (2) 12 and 19 2/12ths gives jack splays by foot-span figures. Slid to the same spacing, the square shows the same jack variation.

measurement across plates is then seen to be 18′ 1½″. Deducting 1½″ as thickness of the ridge gives us 18′ as the span of both rafters, equalling 9′ for the span of one, which settles our run or span figure for use upon the square. Scaling upon the drawings, in the 9′ run we get a corresponding rise of 11′ 3″, which gives us the second figure for use upon the square. Rafter run 9′ and rafter rise 11′ 3″ give rafter cuts as shown in this illustration. This pair of figures will also mark correct bevels for every horizontal or vertical timber that must fit upon or below the roof slope. Vertical timbers, such as gable studs, are marked by the vertical or rise figure. Dormer plates or other horizontal timbers are fitted to the roof slope with a cut marked on the horizontal or run side. To obtain rafter length, we set this same pair of figures to one edge of a board, and we chisel-strike both points, as if it were intended to set out the cuts there. With edge of the blade we measure off the distance at one-twelfth scale between these points, getting about 14′ 5″ for length of the rafter. With rafter length and rafter cuts known, we may set out the pattern. If the top edge of our rafter must cut down to plate arris in a birdsmouth, there is no backing to be allowed, and we may mark off the given measurement direct from tip to toe. If rafter tails are to be provided for, the rafter must run past the plate, and a rafter throat takes the place of the birdsmouth. We may give the rafter any backing that we see fit, but it is plain that we are now lifting the whole roof vertically above the plate lines. Measurements made square from the back of pitched timbers will lift the timber by different amounts corresponding to the different pitch, but all plumb lines are alike, whether measured upon rafters, jacks, hips or valleys. If we should attempt to measure off a 2″ square backing to rafters and jacks, they will stand high when matched against hips and valleys that have been given the same 2″ square backing, because 2″ measured square from a sharp pitch lifts the timber more than 2″ measured square from a flat inclination. But a plumb backing measured down the rafter pattern will match up exactly with the same plumb backing measured down a hip or valley, for all plumb lines are alike and a measurement made upon one will agree exactly with the same measurement made upon any other timber. Size of our roofing timbers and the pitch of our roof will regulate the plumb backings that we prefer to give, but for 4″ by 2″ and a 45° pitch a 4″ plumb backing, as shown in this illustration, will be exactly suitable. Rafter cuts are given by 9′ and 11′ 3″ upon the square, rafter length from plumb of plate to plumb of ridge is known to be 14′ 5″, and on the plumb line at plate end we set down the 4″ plumb backing and so complete the plate throat. If the rafter is to make some given projection, we may now mark this off upon the pattern. If the rafter is to come down to a given course, we may set out our rafter foot by this measurement. Projecting to a given fascia or dropping to a given course as shown by the architect, we put in the appropriate plumb or seat bevel on the pattern, and have completed the pattern rafter.

Patterns by Stepped Figures

By our first method rafter lengths have been found from diagonal measurements made directly across the square, but still other steel-square systems start with the same original figures and finish with a similar result. In place of a measurement made across the square, or as a check upon this measurement, we may choose to step our given rise and run figures twelve times up the rafter pattern. Setting in the present case to 9′ on tongue and 11′ 3″ on blade, we step these twelfth-scale figures twelve times up the pattern and so secure the full-sized rafter length. By the first method we measure an actual distance of 14 5/12ths and set it out as 14′ 5″, thus multiplying our measured figure by twelve. By the second system we step the square containing 14 5/12ths along its diagonal twelve times up the pattern, giving a finished rafter length of 14′ 5″.

Going still further, the foot-span method may be used to obtain similar results. A rafter that is to rise 11′ 3″ and run 9′ will rise 15′ in a 12′ run, equalling a 15″ rise in one foot of span. Then 12 on tongue and 15 on blade now give exactly the same cuts for the rafter pattern that were first given by 9′ on tongue and 11′ 3″ on blade. With pitch figures settled for the foot of span, we can now set the square to 12 on tongue and 15 upon blade, and step these figures up the rafter nine times, to obtain finished rafter length for the required 9′ of span. By the second method we obtained our rafter length by stepping a 9″ span twelve times up the pattern. By this third system we step the pitch figures for one foot of span nine times up the pattern. Plainly both results should be alike, for twelve times nine is identical with nine times twelve, but by the third system there are only nine steps in place of twelve, chances for small inaccuracies are lessened, and the resulting accuracy should be slightly greater. If a purlin is to set up above plate level by some definite measurement, we may step this rise up the rafter to these pitch figures. Where the architect wishes to obtain a definite room size between opposite ashlar throats or purlins, we may start at the ridge end and step out half this span upon the rafter pattern. If dormer trimmers are to be set in upon the pattern, plainly their heights above plates will be known, and may be stepped up with these pitch figures. All vertical or horizontal measurements may be stepped out with the pitch figures upon the rafter pattern, with the same speed and accuracy that are possible with direct measurements made with a rule.

Rafter Lengths from Ready-figured Tables

Still greater speed and accuracy can be secured from reliable tables supplying ready-figured lengths. Diagonal measurements or either method of stepping may then be retained as checks, but all the delays and petty inaccuracies of the older methods are avoided. With the

known roof pitch, given either in inches of rise to the foot or by degrees, we turn to these tables and take out rafter length. For the 9′ span and 15″ pitch this is given as 14′ 4 10/12ths, showing that our diagonal measurement has actually been nearly one-quarter of an inch in error. Experienced roofers will recognise that nothing but the steel square can secure even this degree of accuracy, and nothing but the later figured methods of steel-square use will allow it to be improved upon. By this last method we have only to measure off 14′ 4 10/12ths along the pattern, and set in plumb and seat cuts to the 12 and 15 bevels. Speed is improved, accuracy ensured and possibility of errors is eliminated. But a set of these tables would occupy space which is not available in this section, and would duplicate existing matter by the same writer, which is not desirable. Ready-figured tables giving lengths for rafters, jacks, hips and valleys, of any span and any pitch, whether stated by degrees or in inches of rise, have been calculated for roofing purposes by the present writer, and may be found in the fourth volume of *House and Cottage Construction,* issued by the publishers of this work.

Setting-out Hips and Valleys to Twelfth-scale Figures

If every rafter around a roof runs directly inward for a span of 9′, then very plainly the hip or valley will span the diagonal of a square with 9′ sides. With the steel square we find the length of this diagonal. Setting 9′ on tongue and 9′ on blade to one edge of a board, we again chisel-strike along both arms and measure off the diagonal length as about 12′ 9″. Then just as 9′ supplies span for the rafters, so 12′ 9″ gives span figure for the hip or valley. Rafters, hips and valleys all rise to one level, so 11′ 3″, the rafter rise, is also rise figure for the hips and valleys. Then with 12′ 9″ hip run on tongue and 11′ 3″ rise on blade, we have plumb and seat cuts for the hips and valleys. To get cutting lengths for these timbers, we set this pair of figures to one edge of the board, and chisel-striking the two points gives us about 17′ as lengths for hips and valleys. With lengths, cuts and plumb backing known, we may set out and cut these timbers. Hip splays will also be needed, but, as shown in the illustration, are supplied by 12′ 9″, hip run, on tongue, and 17′, hip length, on blade. If the length line is squared across edges of all hips and valleys as they lie upon the stools, on a hip we shall make this line the long point of our splay. On a valley this is the short point from which the splay commences.

Stepping Hips and Valleys

Just as the twelfth-scale rafter figures may be stepped twelve times up the pattern to produce the full-sized rafter pattern, so our twelfth-scale hip or valley figures can be stepped twelve times up the timber to supply the full-sized hip or valley. Setting hip run, 12′ 9″, and rise, 11′ 3″, to one-twelfth scale, we may step this pair of figures twelve times

up the timber. It will be seen that this is simply a graphic method of multiplication, which substitutes several small errors due to difficulty in bringing the square accurately to position at every step, for one substantial error due to difficulty in reading a twelfth-scale diagonal measurement made across the square with sufficient accuracy to permit of it being increased twelve times when the measurement is laid off to full size.

Once more the foot-span method is available. When rafter pitch is 12 and 15, then hip or valley pitch is known immediately to be 17 and 15. Using a permanent rafter run of 12″, we measure off the diagonal of a square with 12″ sides to get a permanent run for the hip or valley. As nearly as this measurement can be made, we shall find it to be 17″. To get hip and valley cuts by the foot-span system we simply change the 12 on tongue to 17, and the cuts are correct without further trouble. To obtain lengths for hips and valleys at a 9′ span, we may step 17 and 15 nine times up the timber. Every foot of rafter span corresponds to a 17″ span upon the hip or valley, and by stepping 17′ nine times we secure hip or valley length for the 9′ rafter span.

Lengths from Hip or Valley Tables

Once more we may refer direct to figured tables for these lengths. Turning to these tables in the volume mentioned, we find that for the 15″ pitch and 9′ span, length for the hips and valleys is 16′ 11 10/12″. No diagonal measurements across the square are involved in this method, and there are no pitch figures to be stepped. With cuts known as 17 and 15, length taken from the tables as 16′ 11 10/12″, and our 4″ plumb backing, we have all the information at hand that is needed for cutting these hips and valleys.

Jack Rafters and Purlin Mitres

As shown in the same full-page illustration, all jack splays are cut with 9′ span on tongue and 14′ 5″ rafter length upon blade. Marking along blade gives us the jack splay. Marking by the tongue figure supplies top cut for lying purlins and face cut for roof-boarding that is to mitre to a hip or valley. Looking at these two cuts in a roof, one will be seen to be exactly at right angles with the other, so that the same pair of figures produce both. Side cuts for lying purlins are had with roof rise 11′ 3″ on tongue and rafter length 14′ 5″ on blade. The cut is found upon tongue, and is also correct for edge cuts to roof boarding that is to mitre to a hip or valley. Variations in the length of jack rafters will also be needed, and may be had with the same pair of figures that supply the jack splay. Plainly if 14′ 5″ and 9′, which we use to one-twelfth scale upon the square as 14 5/12ths and 9″, give run and spacing of the jack rafters, if jacks can be set at 9″ apart on centres their common difference in length will be 14 5/12ths. Where this spacing is

unsatisfactory we may change it to any other in the same proportion. Setting the steel square to 9 on tongue and 14 5/12ths on blade, we set a straight-edge closely to edge of blade, and slide along this till our required spacing on centres is found upon the tongue. If 2″ rafters are to be set at 12″ spacing, this equals 14″ on centres. With the square set to 9 and 14 5/12ths, we slide it forward along the runner till the tongue shows 14″, and 22 6/12ths which appears on blade is the difference in lengths on each successive jack rafter. Sliding to any other required spacing on tongue, without figuring we can read off the corresponding jack variation from the blade.

Where two roofs of similar importance intersect, we shall usually make them meet up at their intersection upon a valley rafter. But small roofs are frequently carried out by completing the main roof first and placing the smaller additions upon it. We may use this method for dormer windows, or the little roofs that are sometimes substituted for lead gutters behind a chimney-stack. In such cases we shall allow the main roof to be completed in one unbroken line, and shall simply plant the smaller roofs upon its back. Once the main roof is completed valleys can no longer be used, for the rafters in both roofs must cut against a valley. In their place we now use a board nailed flat upon the main roof and rising at the required pitch for the addition. These timbers are known as lay boards, valley boards or sleepers and their lengths and bevels are already known. Lay-board length corresponds exactly to length of the valley which might have occupied the same place. For the same roof the same length is correct for hips, valleys and for lay boards. Lay-board cuts are supplied by the same pair of figures that give cuts for the jack splays, 9′ on tongue and 14′ 5″ on blade. Ridge end of the lay board is marked along the blade. Lay-board seat cuts are given by the tongue. The seat backing given to these lay boards will agree with the seat backing measured from the rafters, but since the lay board does not stand plumb, it is now impossible to measure any direct plumb backing. To get a figure that can be measured down the lay-board backing line we gauge a pencil line along some stuff at a distance corresponding to the plumb backing that has been given to the roof. Striking the rafter seat cut across this space, we measure the length along this line and have the lay-board backing figure. Since we are giving the present roof a 4″ plumb backing, we strike the 9′ and 11′ 3″ bevel across a piece of 5″ stuff, and the distance measured along the seat bevel is found to be about $4\frac{3}{4}$″. This distance is now to be measured down the lay-board backing line for position of the lay-board seat cut. Jack rafters that cut down upon a lay board are cut with seat bevel and jack splay in place of the plumb cut and splay, as found on hip and valley jacks. Their lengths and spacings are unchanged.

Purlins that stand with vertical sides fitting into plumb purlin throats simply mitre up to the hips and valleys with the 45° mitre, 12 and 12. Their side cuts are squared from the upper edge. The little cuts that fit

beneath hip or valley are given by rise, 11′ 3″ on tongue, and double the run figure, which is now 18′ on blade. Purlins standing square to the rafters are sometimes specified in preference to vertical stuff. No throats are cut, and all rafters are left with full strength, but as the roof pitch increases these square purlins get still nearer the horizontal position, where the timber has its minimum value. Edge or top cuts for these lying purlins are given by the same pair of figures that have already supplied jack splays and lay-board cuts, 9′ run and 14′ 5″ rafter length. Looking at the actual roof it will be seen that purlins and jack rafters stand at the square angle with each other. The jack rafter is cut by marking this pair of figures along the blade. Then the top or edge cut for lying purlins will be had by marking the same pair of figures by the tongue. For side cut of these lying purlins we use rise figure, 11′ 3″, on tongue, and rafter length, 14′ 5″, on blade. Cuts that mitre up our roof boards into hips and valleys may be needed. Plainly these boards mitre up above the rafters exactly as the pitched purlins mitre up below the roof, and the same figures will supply their cuts. Then run and rafter length, which are 9′ and 14′ 5″ in the present roof, will mark the face cuts of our roof boards, and rise and rafter length, 11′ 3″ and 14′ 5″ in the current instance, give cuts upon their edges.

CHAPTER XIV

ROOFING TO IRREGULAR PITCHES

Rafters for the Steeper Pitch—Irregular Hips and Valleys—Jack Rafter Cuts and Lengths.

Rafters for the Steeper Pitch

Perhaps our building varies in width, as seen in Fig. 258, but the rafters still run from level plates to a level ridge. We have two different rafter spans and two different pitches, with irregular intersections at the hips and valleys. The main plate has been made of exactly the same width as in the previous example, and the rise is also the same. The main rafter still spans 9′ and rises 11′ 3″, and the setting-out last given will still serve for the main rafter. But the wing introduces a new measurement across 9″ brick walls of 15′ 11½″. Plates still set flush inside, and we begin by totalling up our deductions as before. Each plate still sets in 5″ from face of brickwork or 10″ in all. Adding 1½″ to this figure for thickness of ridge gives us a total of 11½″ to be deducted from brickwork sizes, getting 15′ as span of two rafters, or 7′ 6″ as run of one. The rise is known to be that of the main rafter, since both ridges are level, so 7′ 6″ run on tongue with 11′ 3″ rise on blade supply cuts for the wing rafter pattern. The cutting figures are just as easily obtained and just as easily employed as those already used for the main roof, but their pitch is considerably steeper. Setting 7′ 6″ on tongue and 11′ 3″ on blade to one edge of a board, we mark the points and measure off this distance for wing rafter length, about 13′ 7″. Rafters and hips in our main roof stood at different pitches, but measuring our backing distance upon a plumb line which is always the same, brought the upper edges of all our timbers flush. Measuring the same plumb backing upon the rafter of our new pitch ensures that this also stands at the same vertical distance above the plate arris, and finishes flush with backs of the timbers of every other pitch. Then cuts upon the new wing pattern are set out with 7′ 6″ on tongue and 11′ 3″ on blade, rafter length is the diagonal distance which we measure off between these points as 13′ 7″, and our plumb throat backing is still 4″. With these facts known we may set out the steeper pattern.

As before, we may set the square to 7′ 6″ and 11′ 3″, and can step these figures twelve times up the stuff to secure full-sized results. We may choose to do this to check results obtained by other methods, or we can make this our original method of setting out the pattern, and may employ

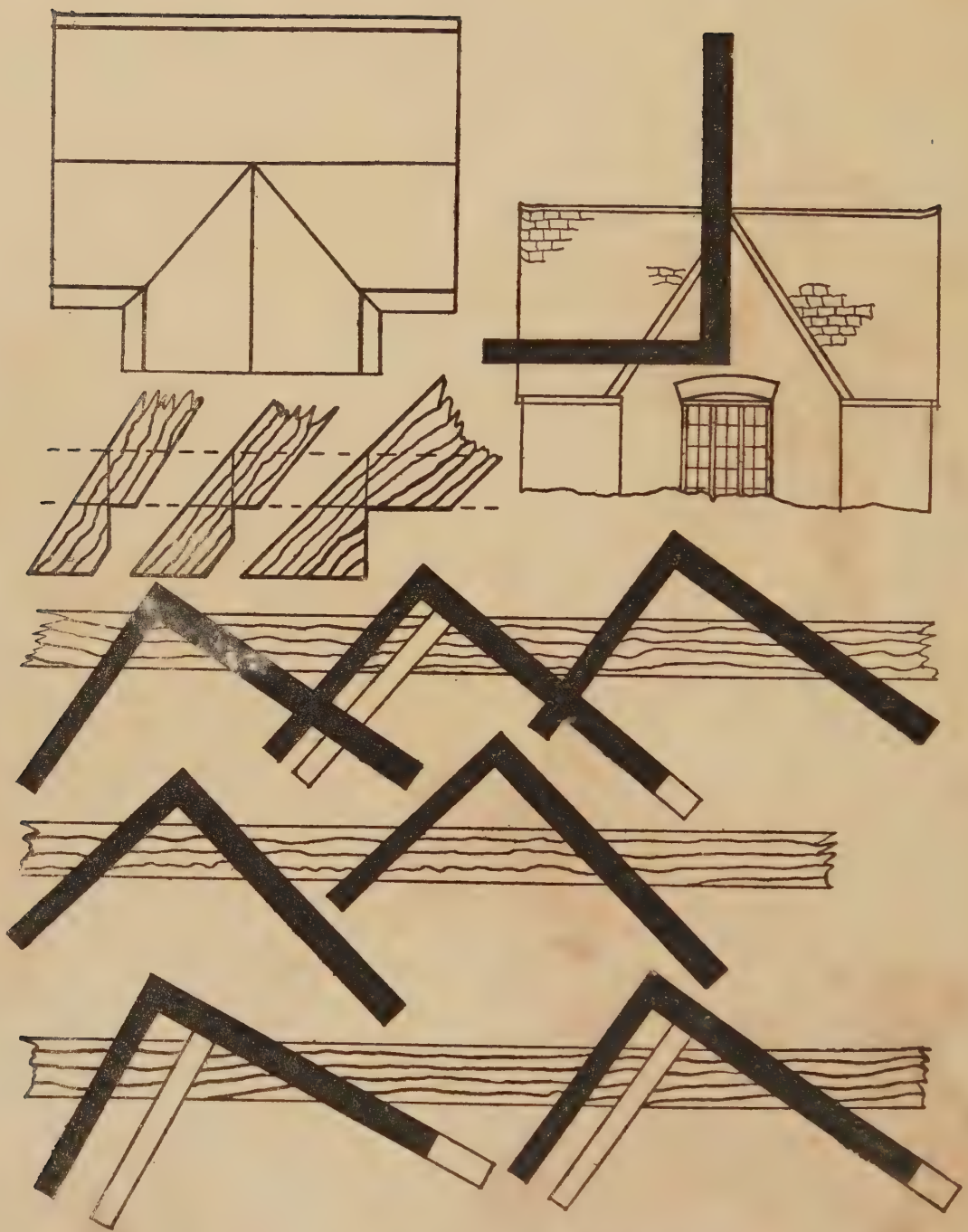


FIG. 258.—UNEVEN-PITCHED ROOFWORK.
For explanation see at foot of opposite page.

still other systems to supply checks upon our operations. By figuring or by sliding upon the square we may determine the pitch of this roof to one foot of span, and shall then find that the wing rafter rises 18″ to the 12″ span. Setting this time to 12 upon tongue and 18 on blade, we may step seven times up the rafter for the 7′ of span, adding the odd 6″ of span with steel square or rule to complete the 7′ 6″ that is required. A smaller number of steps is required than by the previous system, but the result corresponds.

Any purlins that have been put in by height above the plate on the main pattern may now be stepped up to the same height upon the new pitch. They are set at the same plumb distance above the plate, and both purlins will meet in a level intersection at all points where the two different pitches intersect.

But the figured method is again available, and on reference to the tables mentioned we find that for a span of 7′ 6″ and the 18″ pitch, rafter length is accurately 13′ 6¼″.

Irregular Hips and Valleys

When both rafters on our first roof had a span of 9′, the hip travelled diagonally across a square of 9′ sides. Our main rafter still spans 9′, but the new wing rafter has a span of only 7′ 6″. Yet the hip or valley still stands diagonally across an oblong of these given dimensions. With the main rafter it runs 9′ inward to the main ridge. With the wing rafter it runs inward 7′ 6″ to ridge of the wing roof. Setting 9′ and 7′ 6″ to a board, we mark this distance and measure it off as 11′ 2″. Just as 9′ is spanned by the main rafter and 7′ 6″ is spanned by the wing, so 11′ 2″ is the direct distance spanned by this irregular hip or valley. Then hip run 11′ 2″ on tongue and roof rise 11′ 3″ on blade provides plumb and seat cuts for the irregular hip and valley. Setting these two figures upon a board and chisel-striking them for accuracy, we have hip and valley length as about 15′ 10″. Since the hip or valley to an irregular

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Upper line.—(1) A roof measures 18′ 11½″ across main plates and 15′ 11½″ over wing plates. The main rafter spans 9′, and the wing rafter spans 7′ 6″. (2) In the main span of 9′ and wing span of 7′ 6″ the roof rises 11′ 3″.

Second line.—Give the same plumb backing to jacks and rafters of both pitches, and to all hips and valleys.

Third line.—(1) 7′ 6″ run and 11′ 3″ rise gives wing rafter cuts. Distance between these points shows wing rafter length as 13′ 7″. (2) White square, 7′ 6″ wing run and 9′ main run give a diagonal measurement of 11′ 2″ as hip or valley run by twelfth-scale figures. Black square, 10″ foot-span wing run, with 12″ foot-span main run, give 15 8/12ths as foot-span figures for hip or valley run. (3) 12 and 18 gives wing rafter cuts by their foot-span figures.

Fourth line.—(1) 11′ 2″ twelfth-scale hip run with 11′ 3″ rise gives hip and valley cuts. Diagonal distance between these points gives hip and valley length 15′ 10″. (2) 15 8/12ths and 15 gives duplicate hip and valley cuts from the foot-span figures.

Fifth line.—(1) White square, 7′ 6″ wing run with 14′ 5″ main rafter length gives the main jack splay by twelfth-scale methods. Black square, 10″ wing run with 19½″ main rafter length gives main jack splays from foot-span figures. Sliding these squares till jack spacing is read on tongue shows jack variation on blade. (2) White square, 9′ twelfth-scale main rafter run and 13′ 7″ wing rafter length gives wing jack splay to twelfth-scale figures. Black square, 12″ main run with 17 4/12ths wing rafter length gives wing jack splays to foot-span figures. Sliding to this angle on setting jack spacings upon tongue, jack variation may be taken off from blade.

intersection approaches its ridges at an irregular angle, there are now two different ridge splays required. To get the figures that produce them, we set to the two rafter runs, 9′ and 7′ 6″, and slide till the hip run, 11′ 2″, is read on each arm in turn. Reading the result found upon the opposite arm at each setting, we get 9′ 4″ and 13′ 5″. Then 9′ 4″ on tongue and 15′ 10″ hip length cuts the sharp hip splay, while 13′ 5″ on tongue and 15′ 10″ on blade cuts the flat hip or valley splay. With lengths, plumb and seat cuts, splays, and plumb backing known, we proceed to set out our irregular hips and valleys, just as easily as if they belonged to a roof of even pitch.

If any man prefers to set his square to 11′ 2″ on tongue and 11′ 3″ on blade and step these figures twelve times up the timber, there is no reason to be offered to the contrary. If he makes his original measurements accurately and places the square carefully at each step, his results will be a little more accurate than by the single twelfth-scale measurement. If handled carelessly these markings will give results that are just a little more in error. The foot-span system may also be used for these hips and valleys. Our main rafter spans 9′. Our wing rafter spans 7′ 6″. Adding one-third to each side, or sliding upon the square, we see that if the main run were 12′ then the wing run would be 10′. Plainly then for a 12″ main span the corresponding wing span is now 10″. Then the hip or valley travels diagonally across this distance. On the square or from tables we find the diagonal hip or valley run to be 15 8/12ths. Then with hip run 15 8/12″ and main pitch 15″, we have our hip and valley plumb and seat cuts as before. We may step the foot-span figures nine times up the timber, since there are 9′ in the main rafter span. For the hip splays we now set to the foot-span run figures, 12″ and 10″, and slide the square at this angle till 15 8/12ths appears in turn upon each arm. The two figures found in turn upon the opposite arm are the two tongue figures that now produce the two hip splays, while the blade figure that is used for both is had by measuring from 15 8/12″ hip run to 15″ roof rise. Again the same original measurements produce the same lengths and the same bevels by the same combinations, but the actual cutting figures differ with the different methods that we select to work with.

Jack Rafter Cuts and Lengths

When pitches are alike on each side of the hips or valleys, then the jack cuts and jack variations are also alike. As the pitches are altered, so the jack lengths and jack cuts also change, and separate lengths and bevels are needed for each pitch. Taking jack rafters to the main roof first, their splays are given by main rafter length on blade and wing rafter run on tongue. In figures for the particular roof under discussion these are 14′ 5″ and 7′ 6″, giving a much sharper jack splay. The plumb cut for jacks to the main roof is always that of the main rafter. From

the jack-splay figures we get variation in lengths of the jack rafters, either by figuring or by sliding upon the square. If jacks are to be set out at 13″ spaces or 15″ centres, then by doubling both figures we have 2′ 4 10/12″ as variation in lengths for the 15″ spacing. Setting the square to the jack-splay bevel, 7′ 6″ and 14′ 5″, we may slide at this angle till any other chosen spacing appears on tongue, when the corresponding difference in lengths of the jack rafters is shown on blade.

Jack splays for the wing roof are always given by wing rafter length and main rafter run, for our present roof 13′ 7″ and 9′. Again, plumb and seat cuts to the jacks are identical with those to the wing rafters. From these figures for the jack splays we obtain difference in lengths for successive jack rafters. Jacks 18″ on centres are now 2′ 3 2/12″ different each time in length.

By figuring or by sliding upon the square, we may deduce the corresponding variation in length for any other spacing that is called for.

But the foot-span method may also be applied to the jack splays and to jack variations. Where the main rafter spans 1′, then the wing rafter span is 10″. For the 12″ main span the main rafter length is 19¼″. For the 10″ wing span the wing rafter has a length of 17 4/12″. The foot-span figures are different, but the combinations which produce all cuts are the same. Main rafter length and wing rafter span, now 19¼ and 10, give the main jack splays. Wing rafter length and main rafter span, now 17 4/12 and 12, gives splays for the wing jack rafters. With the jack-splay figures we get our jack variations by sliding or by figuring as before.

Where slates or tiles simply cut down to an open valley gutter, and hips are capped with ridge tiles, it is not imperative to maintain level courses with all boards, and each roof face may then very well be boarded independently. But if valley tiles or bonnet hips are employed, boards or battens must now be placed so that each course is carried around the building at one level. With boards of uniform width and even roof pitches this result follows automatically. With irregular intersections it must be brought about intentionally by the roofer. Either the full-sized or the foot-span rafter figures will show the proportion that one roof length bears to the other.

We have just seen that by the foot-span figures when the main rafter has a length of 19¼″, then the wing rafter length is 17 4/12″. To carry the tiles around all pitches in level courses, the same number of boards that cover a space of 19¼″ upon the main roof, must be closed in until they occupy a space of only 17 4/12″ upon the sharper pitch. Setting the steel square to the two figures and sliding to read a 4″ tile gauge, we see that if the main pitch is boarded or battened first to 4″ courses, then battens upon the wing pitch must be set closer so that the wing can be battened to only 3 7/12″ gauge. If by mistake the main pitch is boarded first to 4″ gauge, then the same proportions upon the square show that the wing battens must be opened out to a gauge of about 4 5/12″, which

is greater than many tiles will carry with any prospect of permanent satisfaction.

All other cuts that are given by the jack-splay figures on roofs of even pitch are also found from figures for the jack-splays obtained for roofs of two different intersecting pitches. Ridge cuts to the lay boards are marked by the blade. Setting to the same jack-splay figures but marking by the tongue, we have seat cuts to the lay boards, edge cuts for lying purlins, and face cuts for roof boards that must mitre up to a hip or valley. Lay-board lengths still agree exactly with lengths of the irregular valleys that might have occupied the same positions.

EVEN RISE ROOFING TABLES

EVEN RISE ROOFING TABLE, GIVING LENGTHS

Inches of rise in one foot.	Span of Rafter.									
	1	2	3	4	5	6	7	8	9	10
1	1– 0– 1	2– 0– 1	3– 0– 2	4– 0– 2	5– 0– 3	6– 0– 3	7– 0– 4	8– 0– 4	9– 0– 5	10– 0– 5
2	1– 0– 2	2– 0– 4	3– 0– 6	4– 0– 8	5– 0–10	6– 1– 0	7– 1– 2	8– 1– 4	9– 1– 6	10– 1– 8
3	1– 0– 4	2– 0– 9	3– 1– 1	4– 1– 6	5– 1–10	6– 2– 3	7– 2– 7	8– 2–11	9– 3– 4	10– 3– 8
4	1– 0– 8	2– 1– 4	3– 1–11	4– 2– 7	5– 3– 3	6– 3–11	7– 4– 7	8– 5– 2	9– 5–10	10– 6– 6
5	1– 1– 0	2– 2– 0	3– 3– 0	4– 4– 0	5– 5– 0	6– 6– 0	7– 7– 0	8– 8– 0	9– 9– 0	10–10– 0
6	1– 1– 5	2– 2–10	3– 4– 3	4– 5– 8	5– 7– 1	6– 8– 6	7– 9–11	8–11– 4	10– 0– 9	11– 2– 2
7	1– 1–11	2– 3– 9	3– 5– 8	4– 7– 7	5– 9– 6	6–11– 4	8– 1– 3	9– 3– 2	10– 5– 0	11– 6–11
8	1– 2– 5	2– 4–10	3– 7– 3	4– 9– 8	6– 0– 1	7– 2– 6	8– 4–11	9– 7– 5	10– 9–10	12– 0– 3
9	1– 3– 0	2– 6– 0	3– 9– 0	5– 0– 0	6– 3– 0	7– 6– 6	8– 9– 0	10– 0– 0	11– 3– 0	12– 6– 0
10	1– 3– 8	2– 7– 3	3–10–11	5– 2– 6	6– 6– 2	7– 9– 9	9– 2– 5	10– 7– 0	11– 9– 8	13– 0– 3
11	1– 4– 3	2– 8– 7	4– 0–10	5– 5– 1	6– 9– 5	8– 1– 8	9– 5–11	10–10– 3	12– 2– 6	13– 6– 9
12	1– 5– 0	2– 9–11	4– 2–11	5– 7–11	7– 0–11	8– 5–10	9–10–10	11– 3–10	12– 6– 9	14– 1– 9
13	1– 5– 8	2–11– 5	4– 5– 1	5–10– 9	7– 4– 6	8–10– 2	10– 3–10	11– 9– 6	13– 3– 3	14– 8–11
14	1– 6– 5	3– 0–11	4– 7– 4	6– 1– 9	7– 8– 2	9– 2– 8	10– 9– 1	12– 3– 6	13– 9–11	15– 4– 5
15	1– 7– 2	3– 2– 5	4– 9– 8	6– 4–10	8– 0– 1	9– 7– 3	11– 2 –6	12–11– 8	14– 4–10	16– 0– 1
16	1– 8– 0	3– 4– 0	5– 0– 0	6– 8– 0	8– 4– 0	10– 0– 0	11– 8– 0	13– 4– 0	15– 0– 0	16– 8– 0
17	1– 8–10	3– 5– 7	5– 2– 5	6–11– 3	8– 8– 0	10– 4–10	12– 1– 8	13–10– 6	15– 7– 3	17– 4– 1
18	1– 9– 8	3– 7– 3	5– 4–11	7– 2– 6	9– 0– 2	10– 9–10	12– 7– 5	14– 5– 1	16– 2– 8	18– 0– 4
19	1–10– 6	3– 8–11	5– 7– 5	7– 5–11	9– 4– 4	11– 2–10	13– 1– 4	14–11– 9	16–10– 3	18– 8– 9
20	1–11– 4	3–10– 8	5–10– 0	7– 9– 4	9– 8– 8	11– 7–11	13– 7– 3	15– 6– 7	17– 5–11	19– 5– 3
21	2– 0– 2	4– 0– 5	6– 0– 7	8– 0– 9	10– 0–11	12– 1– 2	14– 1– 4	16– 1– 6	18– 1– 8	20– 1–10
22	2– 1– 1	4– 2– 1	6– 3– 2	8– 4– 3	10– 5– 4	12– 6– 4	14– 7– 5	16– 8– 6	18– 9– 7	20–10– 7
23	2– 1–11	4– 3–11	6– 5–10	8– 7– 9	10– 9– 9	12–11– 8	15– 1– 8	17– 3– 7	19– 5– 6	21– 7– 5
24	2– 2–10	4– 5– 8	6– 8– 6	8–11– 4	11– 2– 2	13– 5– 0	15– 7–10	17–10– 8	20– 1– 6	22– 4– 4
25	2– 3– 9	4– 7– 6	6–11– 3	9– 2–11	11– 6– 8	13–10– 5	16– 2– 2	18– 5–11	20– 9– 8	23– 1– 5

EXAMPLE SHOWING USE

Read the rafter span found at head of this table in feet, in inches, or in rise to the foot of span are to be read in feet, in inches, or in twelfths accord- 6 *feet* to have a rafter length of 10 *feet*, for a span of 6 *inches* it has a rafter 10 *twelfths*. Then a rafter of 16″ pitch, that is to span 6′ 6¾″, will have a

EVEN RISE ROOFING TABLE, GIVING LENGTHS

Inches of rise in one foot.	Span of Rafter.									
	1	2	3	4	5	6	7	8	9	10
1	1– 5– 0	2–10– 0	4– 3– 0	5– 8– 0	7– 1– 0	8– 6– 0	9–11– 0	11– 4– 0	12– 9– 0	14– 2– 0
2	1– 5– 1	2–10– 2	4– 3– 3	5– 8– 4	7– 1– 5	8– 6– 6	9–11– 7	11– 4– 8	12– 9– 9	14– 2–11
3	1– 5– 3	2–10– 6	4– 3– 9	5– 8–11	7– 2– 2	8– 7– 5	10– 0– 8	11– 5–11	12–11– 2	14– 4– 5
4	1– 5– 5	2–10–11	4– 4– 4	5– 9– 9	7– 3– 2	8– 8– 7	10– 2– 1	11– 7– 6	13– 0–11	14– 6– 3
5	1– 5– 8	2–11– 5	4– 5– 1	5–10– 9	7– 4– 6	8–10– 2	10– 3–10	11– 9– 6	13– 3– 3	14– 8–11
6	1– 6– 0	3– 0– 0	4– 6– 0	6– 0– 0	7– 6– 0	9– 0– 0	10– 6– 0	12– 0– 0	13– 6– 0	15– 0– 0
7	1– 6– 4	3– 0– 9	4– 7– 1	6– 1– 5	7– 7– 9	9– 2– 2	10– 8– 6	12– 2–10	13– 9– 3	15– 3– 7
8	1– 6– 9	3– 1– 6	4– 8– 3	6– 3– 1	7– 9–10	9– 4– 7	10–11– 4	12– 6– 1	14– 0–10	15– 7– 7
9	1– 7– 2	3– 2– 5	4– 9– 8	6– 4–10	8– 0– 1	9– 7– 3	11– 2– 6	12– 9– 8	14– 4–11	16– 0– 1
10	1– 7– 8	3– 3– 5	4–11– 1	6– 6–10	8– 2– 6	9–10– 2	11– 5–11	13– 1– 7	14– 9– 3	16– 5– 0
11	1– 8– 3	3– 4– 5	5– 0– 8	6– 8–11	8– 5– 2	10– 1– 4	11– 9– 7	13– 5–10	15– 2– 0	16–10– 3
12	1– 8– 9	3– 5– 7	5– 2– 4	6–11– 2	8– 7–11	10– 4– 8	12– 1– 6	13–10– 3	15– 7– 1	17– 3–10
13	1– 9– 5	3– 6– 9	5– 4– 2	7– 1– 6	8–10–11	10– 8– 3	12– 5– 8	14– 3– 0	16– 0– 5	17– 7– 9
14	1–10– 0	3– 8– 0	5– 6– 0	7– 4– 0	9– 2– 0	11– 0– 0	12–10– 0	14– 8– 0	16– 6– 0	18– 4– 0
15	1–10– 8	3– 9– 4	5– 7–11	7– 6– 7	9– 5– 3	11– 3–11	13– 2– 7	15– 1– 2	16–11–10	18–10– 6
16	1–11– 4	3–10– 8	5–10– 0	7– 9– 4	9– 8– 7	11– 7–11	13– 7– 3	15– 6– 7	17– 5–11	19– 5– 3
17	2– 0– 0	4– 0– 1	6– 0– 1	8– 0– 1	10– 0– 2	12– 0– 2	14– 0– 2	16– 0– 3	18– 0– 3	20– 0– 3
18	2– 0– 9	4– 1– 6	6– 2– 3	8– 3– 0	10– 3– 8	12– 4– 5	14– 5– 2	16– 5–11	18– 6– 8	20– 7– 5
19	2– 1– 6	4– 2–11	6– 5– 4	8– 5–11	10– 7– 5	12– 8–10	14–10– 4	16–11–10	19– 1– 4	21– 2– 9
20	2– 2– 3	4– 4– 6	6– 6– 8	8– 8–11	10–11– 2	13– 1– 5	15– 3– 7	17– 5–10	19– 8– 1	21–10– 4
21	2– 3– 0	4– 6– 0	6– 9– 0	9– 0– 0	11– 3– 0	13– 6– 0	15– 9– 0	18– 0– 0	20– 3– 0	22– 6– 0
22	2– 3– 9	4– 7– 7	6–11– 4	9– 3– 2	11– 6–11	13–10– 9	16– 2– 6	18– 6– 5	20–10– 1	23– 1–10
23	2– 4– 7	4– 9– 2	7– 1– 9	9– 6– 4	11–10–11	14– 3– 6	16– 8– 1	19– 0– 8	21– 5– 3	23– 9–10
24	2– 5– 5	4–10– 9	7– 4– 2	9– 9– 7	12– 3– 0	14– 8– 4	17– 1– 9	19– 7– 2	22– 0– 7	24– 5–11
25	2– 6– 3	5– 0– 5	7– 6– 8	10– 0–10	12– 7– 1	15– 1– 4	17– 7– 6	20– 1– 9	22– 7–11	25– 2– 2

EXAMPLE SHOWING USE

At head of this table read the same span that you have used for your hip and valley lengths given for every inch of rise in the table are also to rise 14″ in one foot, for a rafter span of 6 *feet*, we have a hip and valley for a span of 6 *twelfths* (or ½″) we have a hip length of 11 *twelfths*. Then for 11–11–11, or, in full, 11 feet 11 inches and 11 twelfths.

OF RAFTERS FOR EVERY INCH OF RISE

Span of Rafter.										Inches of rise in one foot.
11	12	13	14	15	16	17	18	19	20	
11- 0- 6	12- 0- 6	13- 0- 7	14- 0- 7	15- 0- 8	16- 0- 8	17- 0- 9	18- 0- 9	19- 0-10	20- 0-10	1
11- 1-10	12- 2- 0	13- 2- 2	14- 2- 4	15- 2- 6	16- 2- 8	17- 2-10	18- 3- 0	19- 3- 2	20- 3- 4	2
11- 4- 1	12- 4- 5	13- 4-10	14- 5- 2	15- 5- 7	16- 5-11	17- 6- 3	18- 6- 8	19- 7- 0	20- 7- 5	3
11- 7- 2	12- 7-10	13- 8- 5	14- 9- 1	15- 9- 9	16-10- 5	17-11- 0	18-11- 8	20- 0- 4	21- 1- 0	4
11-11- 0	13- 0- 0	14- 1- 0	15- 2- 0	16- 3- 0	17- 4- 0	18- 5- 0	19- 6- 0	20- 7- 0	21- 8- 0	5
12- 3- 7	13- 5- 1	14- 6- 5	15- 7-10	16- 9- 3	17-10- 8	19- 0- 1	20- 1- 6	21- 2-11	22- 4- 4	6
12- 8-10	13-10- 9	15- 0- 7	16- 2- 6	17- 4- 5	18- 6- 3	19- 8- 2	20-10- 1	21-11-11	23- 1-10	7
13- 2- 8	14- 5- 1	15- 7- 6	16- 9-11	18- 0- 4	19- 2- 9	20- 5- 2	21- 7- 7	22-10- 0	24- 0- 5	8
13- 9- 0	15- 0- 0	16- 3- 0	17- 6- 0	18- 9- 0	20- 0- 0	21- 3- 0	22- 6- 0	23- 9- 0	25- 0- 0	9
14- 3-11	15- 7- 6	16-11- 2	18- 2- 9	19- 6- 5	20-10- 0	22- 1- 8	23- 5- 3	24- 8-11	26- 0- 6	10
14-11- 1	16- 3- 4	17- 7- 7	18-11-11	20- 4- 2	21- 8- 6	23- 0- 9	24- 5- 0	25- 9- 4	27- 1- 7	11
15- 6- 9	16-11- 8	18- 4- 8	19- 9- 8	21- 2- 7	22- 7- 7	24- 0- 7	25- 5- 7	26-10- 6	28- 3- 6	12
16- 2- 7	17- 8- 4	19- 2- 0	20- 7- 8	22- 1- 5	23- 7- 1	25- 0- 9	26- 6- 5	28- 0- 2	29- 5-10	13
16-10-10	18- 5- 3	19-11- 8	21- 6- 2	23- 0- 7	24- 7- 0	26- 1- 6	27- 7-11	29- 2- 4	30- 8- 9	14
17- 7- 4	19- 2- 6	20- 9- 9	22- 4-11	24- 0- 2	25- 7- 4	27- 2- 7	28- 9- 9	30- 5- 0	32- 0- 2	15
18- 4- 0	20- 0- 0	21- 8- 0	23- 4- 0	25- 0- 0	26- 8- 0	28- 4- 0	30- 0- 0	31- 8- 0	33- 4- 0	16
19- 0-11	20- 9- 8	22- 6- 6	24- 3- 4	26- 0- 1	27- 8-11	29- 5- 8	31- 2- 6	32-11- 4	34- 8- 2	17
19-10- 0	21- 7- 7	23- 5- 3	25- 2-10	27- 0- 6	28-10- 2	30- 7- 9	32- 5- 5	34- 3- 0	36- 0- 8	18
20- 7- 2	22- 5- 8	24- 4- 2	26- 2- 7	28- 1- 1	29-11- 7	31-10- 0	33- 8- 6	35- 7- 0	37- 5- 5	19
21- 4- 7	23- 3-11	25- 3- 3	27- 2- 6	29- 1-10	31- 1- 2	33- 0- 6	34-11-10	36-11- 2	38-10- 6	20
22- 2- 1	24- 2- 3	26- 2- 5	28- 2- 7	30- 2-10	32- 3- 0	34- 3- 2	36- 3- 4	38- 3- 7	40- 3- 9	21
22-11- 8	25- 0- 9	27- 1- 9	29- 2-10	31- 3-11	33- 4-11	35- 6- 0	37- 7- 1	39- 8- 2	41- 9- 2	22
23- 9- 5	25-11- 4	28- 1- 3	30- 3- 2	32- 5- 2	34- 7- 1	36- 9- 0	38-11- 0	41- 0-11	43- 2-10	23
24- 7- 2	26-10- 0	29- 0-10	31- 3- 8	33- 6- 6	35- 9- 4	38- 0- 2	40- 3- 0	42- 5-10	44- 8- 8	24
25- 5- 2	27- 8-10	30- 0- 7	32- 4- 4	34- 8- 1	36-11-10	39- 3- 7	41- 7- 4	43-11- 0	46- 2- 9	25

OF THIS TABLE.

twelfths, as your span requires. Then rafter lengths given for every inch of ingly. Thus a rafter that is to rise 16″ in one foot is shown for a span of length of 10 *inches*, and for a span of 6 *twelfths* (or ½″) it has a rafter length of rafter length of 10-10-10, or, in full, 10 feet 10 inches and 10 twelfths.

OF HIPS AND VALLEYS FOR EVERY INCH OF RISE

Span of Rafter.										Inches of rise in one foot.
11	12	13	14	15	16	17	18	19	20	
15- 7- 0	17- 0- 0	18- 5- 0	19-10- 0	21- 3- 0	22- 8- 0	24- 1- 0	25- 6- 0	26-11- 0	28- 4- 0	1
15- 7-11	17- 1- 1	18- 6- 2	19-11- 3	21- 4- 4	22- 9- 5	24- 2- 6	25- 7- 7	27- 0- 8	28- 5- 9	2
15- 9- 7	17- 2-10	18- 8- 1	20- 1- 4	21- 6- 7	22-11-10	24- 5- 0	25-10- 3	27- 3- 6	28- 8- 9	3
15-11-10	17- 5- 3	18-10- 8	20- 4- 1	21- 9- 6	23- 2- 0	24- 8- 5	26- 1-10	27- 7- 3	29- 0- 9	4
16- 2- 7	17- 8- 4	19- 2- 0	20- 7- 8	22- 1- 5	23- 7- 1	25- 0- 9	26- 6- 5	28- 0- 2	29- 5-10	5
16- 6- 0	18- 0- 0	19- 6- 0	21- 0- 0	22- 6- 0	24- 0- 0	25- 6- 0	27- 0- 0	28- 6- 0	30- 0- 0	6
16- 9-11	18- 4- 4	19-10- 8	21- 5- 0	22-11- 4	24- 5- 9	26- 0- 1	27- 6- 5	29- 0-10	30- 7- 2	7
17- 2- 5	18- 9- 2	20- 3-11	21-10- 8	23- 5- 5	25- 0- 2	26- 6-11	28- 1- 8	29- 8- 6	31- 3- 3	8
17- 7- 4	19- 2- 6	20- 9- 9	22- 4-11	24- 0- 2	25- 7- 4	27- 2- 7	28- 9- 9	30- 5- 0	32- 0- 2	9
18- 0- 8	19- 8- 5	21- 4- 1	22-11- 9	24- 7- 6	26- 3- 2	27-10-10	29- 6- 7	31- 2- 3	32- 9-11	10
18- 6- 6	20- 2- 8	21-10-11	23- 7- 2	25- 3- 4	26-11- 7	28- 7-10	30- 4- 0	32- 0- 3	33- 8- 6	11
19- 0- 8	20- 9- 0	22- 6- 2	24- 3- 0	26-11- 9	27- 8- 7	29- 5- 4	31- 2- 2	32-10-11	34- 7- 8	12
19- 7- 2	21- 4- 6	23- 1-11	24-11- 3	26- 8- 8	28- 6- 1	30- 3- 5	32- 0-10	33-10- 2	35- 7- 7	13
20- 2- 0	22- 0- 0	23-10- 0	25- 8- 0	27- 6- 0	29- 4- 0	31- 2- 0	33- 0- 0	34-10- 0	36- 8- 0	14
20- 9- 2	22- 7-10	24- 6- 5	26- 5- 1	28- 3- 9	30- 2- 5	32- 1- 1	33-11- 8	35-10- 4	37- 9- 0	15
21- 4- 7	23- 3-11	25- 3- 2	27- 2- 6	29- 1-10	31- 1- 2	33- 0- 6	34-11-10	36-11- 2	38-10- 6	16
22- 0- 4	24- 0- 4	26- 0- 4	28- 0- 5	30- 0- 5	32- 0- 5	34- 0- 6	36- 0- 6	38- 0- 6	40- 0- 7	17
22- 6- 2	24- 8-10	26- 9- 7	28-10- 4	30-11- 1	32-11-10	35- 0- 7	37- 1- 4	39- 2- 1	41- 2- 9	18
23- 4- 3	25- 5- 8	27- 7- 2	29- 8- 8	31-10- 2	33-11- 7	36- 1- 1	38- 2- 7	40- 4- 1	42- 5- 6	19
24- 0- 6	26- 2- 9	28- 5- 0	30- 7- 3	32- 9- 5	34-11- 8	37- 1-11	39- 4- 2	41- 6- 5	43- 8- 7	20
24- 9- 0	27- 0- 0	29- 3- 0	31- 6- 0	33- 9- 0	36- 0- 0	38- 3- 0	40- 6- 0	42- 9- 0	45- 0- 0	21
25- 5- 8	27- 9- 5	30- 1- 2	32- 5- 0	34- 8- 9	37- 0- 7	39- 4- 4	41- 8- 2	43-11-11	46- 3- 8	22
26- 2- 5	28- 7- 0	30-11- 7	33- 4- 2	35- 8- 9	38- 1- 4	40- 5-11	42-10-6	45- 3- 1	47- 7- 8	23
26-11- 4	29- 4- 9	31-10- 2	34- 3- 6	36- 8-11	39- 2- 4	41- 7- 8	44- 1- 1	46- 6- 6	48-11-11	24
27- 8- 5	30- 2- 7	32- 8-10	35- 3- 0	37- 9- 3	40- 3- 6	42- 9- 8	45- 3-11	47-10- 1	50- 4- 4	25

OF THIS TABLE.

rafter pattern in feet, in inches, or in twelfths, as your span requires. Then to be read in feet, in inches, or in twelfths accordingly. Thus on a roof that is length of 11 *feet*, for a span of 6 *inches* we have a hip length of 11 *inches*, and the 14″ pitch, when the rafter spans 6′ 6½″, the hip or valley length will be

DEGREE ROOFING TABLE, GIVING LENGTH

Pitch of roof in degrees.	Span of Rafter. 1	2	3	4	5	6	7	8	9	10
12	1– 0– 3	2– 0– 6	3– 0–10	4– 1– 1	5– 1– 4	6– 1– 7	7– 1–11	8– 2– 2	9– 2– 5	10– 2–
13	1– 0– 4	2– 0– 8	3– 0–11	4– 1– 3	5– 1– 7	6– 1–11	7– 2– 2	8– 2– 6	9– 2–10	10– 3–
14	1– 0– 4	2– 0– 9	3– 1– 1	4– 1– 6	5– 1–10	6– 2– 2	7– 2– 7	8– 2–11	9– 3– 4	10– 3–
15	1– 0– 5	2– 0–10	3– 1– 3	4– 1– 8	5– 2– 1	6– 2– 6	7– 3– 0	8– 3– 5	9– 3–10	10– 4–
16	1– 0– 6	2– 1– 0	3– 1– 5	4– 1–11	5– 2– 5	6– 2–11	7– 3– 5	8– 3–10	9– 4– 4	10– 4–1
17	1– 0– 7	2– 1– 1	3– 1– 8	4– 2– 2	5– 2– 9	6– 3– 3	7– 3–10	8– 4– 5	9– 4–11	10– 5–
18	1– 0– 7	2– 1– 3	3– 1–10	4– 2– 6	5– 3– 1	6– 3– 8	7– 4– 4	8– 4–11	9– 5– 7	10– 6–
19	1– 0– 8	2– 1– 5	3– 2– 1	4– 2– 9	5– 3– 5	6– 4– 2	7– 4–10	8– 5– 6	9– 6– 3	10– 6–1
20	1– 0– 9	2– 1– 7	3– 2– 4	4– 3– 1	5– 3–10	6– 4– 8	7– 5– 5	8– 6– 2	9– 6–11	10– 7–
21	1– 0–10	2– 1– 8	3– 2– 7	4– 3– 5	5– 4– 3	6– 5– 2	7– 6– 0	8– 6–10	9– 7– 8	10– 8–
22	1– 0–11	2– 1–11	3– 2–10	4– 3– 9	5– 4– 9	6– 5– 8	7– 6– 7	8– 7– 6	9– 8– 6	10– 9–
23	1– 1– 0	2– 2– 1	3– 3– 1	4– 4– 2	5– 5– 2	6– 6– 3	7– 7– 3	8– 8– 4	9– 9– 4	10–10–
24	1– 1– 2	2– 2– 3	3– 3– 5	4– 4– 7	5– 5– 8	6– 6–10	7– 7–11	8– 9– 1	9–10– 3	10–11–
25	1– 1– 3	2– 2– 6	3– 3– 9	4– 5– 0	5– 6– 2	6– 7– 5	7– 8– 8	8– 9–11	9–11– 2	11– 0–
26	1– 1– 4	2– 2– 8	3– 4– 1	4– 5– 5	5– 6– 9	6– 8– 1	7– 9– 5	8–10–10	10– 0– 2	11– 1–
27	1– 1– 6	2– 2–11	3– 4– 5	4– 5–11	5– 7– 4	6– 8–10	7–10– 3	8–11– 9	10– 1– 3	11– 2–
28	1– 1– 7	2– 3– 2	3– 4– 9	4– 6– 4	5– 7–11	6– 9– 7	7–11– 2	9– 0– 9	10– 2– 4	11– 3–1
29	1– 1– 9	2– 3– 5	3– 5– 2	4– 6–11	5– 8– 7	6–10– 4	8– 0– 1	9– 1– 9	10– 3– 6	11– 5–
30	1– 1–10	2– 3– 9	3– 5– 7	4– 7– 5	5– 9– 3	6–11– 2	8– 1– 0	9– 2–10	10– 4– 8	11– 6–
31	1– 2– 0	2– 4– 0	3– 6– 0	4– 8– 0	5–10– 0	7– 0– 0	8– 2– 0	9– 4– 0	10– 6– 0	11– 8–
32	1– 2– 2	2– 4– 4	3– 6– 5	4– 8– 7	5–10– 9	7– 0–11	8– 3– 1	9– 5– 2	10– 7– 4	11– 9–
33	1– 2– 4	2– 4– 7	3– 6–11	4– 9– 3	5–11– 7	7– 1–10	8– 4– 2	9– 6– 6	10– 8– 9	11–11–
34	1– 2– 6	2– 4–11	3– 7– 5	4– 9–11	6– 0– 5	7– 2–10	8– 5– 4	9– 7– 9	10–10– 3	12– 0–
35	1– 2– 8	2– 5– 4	3– 7–11	4–10– 7	6– 1– 3	7– 3–11	8– 6– 7	9– 9– 2	10–11–10	12– 2–
36	1– 2–10	2– 5– 8	3– 8– 6	4–11– 4	6– 2– 2	7– 5– 0	8– 7–10	9–10– 8	11– 1– 6	12– 4–

EXAMPLE SHOWING U

Read the rafter span found at head of this table in feet, in inches, or of pitch in the table are to be read as feet, as inches, or as twelf have a rafter length of 7 *feet*, for a span of 6 *inches* it has a rafter length Then a rafter of 31° pitch to span 6′ 6½″ will have a length of 7–7–7, or,

DEGREE ROOFING TABLE, GIVING LENGTHS O

Pitch of roof in degrees.	Span of Rafter. 1	2	3	4	5	6	7	8	9	10
12	1– 5– 2	2–10– 4	4– 3– 6	5– 8– 8	7– 1–10	8– 7– 0	10– 0– 1	11– 5– 3	12–10– 5	14– 3–
13	1– 5– 2	2–10– 5	4– 3– 7	5– 8– 9	7– 2– 0	8– 7– 2	10– 0– 4	11– 5– 7	12–10– 9	14– 3–
14	1– 5– 3	2–10– 5	4– 3– 8	5– 8–11	7– 2– 2	8– 7– 4	10– 0– 7	11– 5–10	12–11– 1	14– 4–
15	1– 5– 3	2–10– 7	4– 3–10	5– 9– 1	7– 2– 4	8– 7– 8	10– 0–11	11– 6– 2	12–11– 5	14– 4–
16	1– 5– 4	2–10– 8	4– 3–11	5– 9– 3	7– 2– 7	8– 7–11	10– 1– 3	11– 6– 6	12–11–10	14– 5–
17	1– 5– 4	2–10– 9	4– 4– 1	5– 9– 5	7– 2–10	8– 8– 2	10– 1– 6	11– 6–11	13– 0– 3	14– 5–
18	1– 5– 5	2–10–10	4– 4– 3	5– 9– 8	7– 3– 1	8– 8– 6	10– 1–11	11– 7– 4	13– 0– 9	14– 6–
19	1– 5– 6	2–10–11	4– 4– 5	5– 9–10	7– 3– 4	8– 8–10	10– 2– 3	11– 7– 9	13– 1– 2	14– 6–
20	1– 5– 6	2–11– 1	4– 4– 7	5–10– 1	7– 3– 7	8– 9– 2	10– 2– 8	11– 8– 2	13– 1– 9	14– 7–
21	1– 5– 7	2–11– 2	4– 4– 9	5–10– 4	7– 3–11	8– 9– 6	10– 3– 1	11– 8– 8	13– 2– 3	14– 7–
22	1– 5– 8	2–11– 4	4– 4–11	5–10– 7	7– 4– 3	8– 9–11	10– 3– 7	11– 9– 2	13– 2–10	14– 8–
23	1– 5– 9	2–11– 5	4– 5– 2	5–10–11	7– 4– ″	8–10– 4	10– 4– 0	11– 9– 9	13– 3– 6	14– 9–
24	1– 5–10	2–11– 7	4– 5– 5	5–11– 2	7– 5– 0	8–10– 9	10– 4– 7	11–10– 5	13– 4– 2	14–10–
25	1– 5–10	2–11– 9	4– 5– 7	5–11– 6	7– 5– 4	8–11– 3	10– 5– 1	11–10–11	13– 4–10	14–10–
26	1– 5–11	2–11–11	4– 5–10	5–11–10	7– 5– 9	8–11– 8	10– 5– 8	11–11– 7	13– 5– 7	14–11–
27	1– 6– 0	3– 0– 1	4– 6– 1	6– 0– 2	7– 6– 2	9– 0– 3	10– 6– 3	12– 0– 4	13– 6– 4	15– 0–
28	1– 6– 2	3– 0– 3	4– 6– 5	6– 0– 6	7– 6– 8	9– 0–10	10– 6–11	12– 1– 1	13– 7– 2	15– 1–
29	1– 6– 3	3– 0– 5	4– 6– 8	6– 0–11	7– 7– 2	9– 1– 4	10– 7– 7	12– 1–10	13– 8– 1	15– 2–
30	1– 6– 4	3– 0– 8	4– 7– 0	6– 1– 4	7– 7– 8	9– 2– 0	10– 8– 4	12– 2– 8	13– 9– 0	15– 3–
31	1– 6– 5	3– 0–11	4– 7– 4	6– 1– 9	7– 8– 2	9– 2– 8	10– 9– 1	12– 3– 6	13– 9–11	15– 4–
32	1– 6– 7	3– 1– 1	4– 7– 8	6– 2– 3	7– 8– 9	9– 3– 4	10– 9–11	12– 4– 5	13–11– 0	15– 5–
33	1– 6– 8	3– 1– 4	4– 8– 0	6– 2– 8	7– 9– 5	9– 4– 1	10–10– 9	12– 5– 5	14– 0– 1	15– 6–
34	1– 6–10	3– 1– 7	4– 8– 5	6– 3– 2	7–10– 0	9– 4–10	10–11– 7	12– 6– 5	14– 1– 3	15– 8–
35	1– 6–11	3– 1–11	4– 8–10	6– 3– 9	7–10– 8	9– 5– 8	11– 0– 7	12– 7– 6	14– 2– 5	15– 9–
36	1– 7– 1	3– 2– 2	4– 9– 3	6– 4– 4	7–11– 5	9– 6– 6	11– 1– 7	12– 8– 8	14– 3– 9	15–10–

EXAMPLE SHOWING

At head of this table read the same span that has already been use Then hip and valley lengths given for every degree of roof pitch in the Thus a roof pitched at 30° for a rafter span of 6 *feet* has a hip and v and 2 *twelfths*, and for a span of 6 *twelfths* has a hip length of 9 *twelfths*. 9–11–11, or, in full, 9 feet 11 inches and 11 twelfths.

OF RAFTERS FOR ROOFS OF 12° TO 36° PITCH.

Span of Rafter.										Pitch of roof in degrees.
11	12	13	14	15	16	17	18	19	20	
11- 2-11	12- 3- 3	13- 3- 6	14- 3- 9	15- 4- 0	16- 4- 3	17- 4- 7	18- 4-10	19- 5- 1	20- 5- 4	12
11- 3- 6	12- 3- 9	13- 4- 1	14- 4- 5	15- 4- 9	16- 5- 1	17- 5- 4	18- 5- 8	19- 6- 0	20- 6- 4	13
11- 4- 1	12- 4- 5	13- 4- 9	14- 5- 2	15- 5- 6	16- 5-11	17- 6- 3	18- 6- 7	19- 7- 0	20- 7- 4	14
11- 4- 8	12- 5- 1	13- 5- 6	14- 5-11	15- 6- 4	16- 6- 9	17- 7- 2	18- 7- 7	19- 8- 1	20- 8- 6	15
11- 5- 4	12- 5-10	13- 6- 3	14- 6- 9	15- 7- 3	16- 7- 9	17- 8- 3	18- 8- 8	19- 9- 2	20- 9- 8	16
11- 6- 0	12- 6- 7	13- 7- 2	14- 7- 8	15- 8- 3	16- 8- 9	17- 9- 4	18- 9-10	19-10- 5	20-11- 0	17
11- 6-10	12- 7- 5	13- 8- 0	14- 8- 8	15- 9- 3	16- 9-11	17-10- 6	18-11- 1	19-11- 9	21- 0- 4	18
11- 7- 7	12- 8- 4	13- 9- 0	14- 9- 8	15-10- 5	16-11- 1	17-11- 9	19- 0- 5	20- 1- 2	21- 1-10	19
11- 8- 6	12- 9- 3	13-10- 0	14-10- 9	15-11- 7	17- 0- 4	18- 1- 1	19- 1-10	20- 2- 8	21- 3- 5	20
11- 9- 5	12-10- 3	13-11- 1	14-11-11	16- 0-10	17- 1- 8	18- 2- 6	19- 3- 8	20- 4- 3	21- 5- 1	21
11-10- 4	12-11- 4	14- 0- 3	15- 1- 2	16- 2- 2	17- 3- 1	18- 4- 0	19- 5- 0	20- 5-11	21- 6-10	22
11-11- 5	13- 0- 5	14- 1- 6	15- 2- 6	16- 3- 7	17- 4- 7	18- 5- 7	19- 6- 8	20- 7- 8	21- 8- 9	23
12- 0- 6	13- 1- 8	14- 2- 9	15- 3-11	16- 5- 0	17- 6- 2	18- 7- 4	19- 8- 5	20- 9- 7	21-10- 9	24
12- 1- 8	13- 2-11	14- 4- 2	15- 5- 4	16- 6- 7	17- 7-10	18- 9- 1	19-10- 4	20-11- 7	22- 0-10	25
12- 2-10	13- 4- 3	14- 5- 7	15- 6-11	16- 8- 3	17- 9- 7	18-11- 0	20- 0- 4	21- 1- 8	22- 3- 0	26
12- 4- 2	13- 5- 7	14- 7- 1	15- 8- 7	16-10- 0	17-11- 6	19- 0-11	20- 2- 5	21- 3-11	22- 5- 4	27
12- 5- 6	13- 7- 1	14- 8- 8	15-10- 3	16-11-10	18- 1- 5	19- 3- 1	20- 4- 8	21- 6- 3	22- 7-10	28
12- 6-11	13- 8- 8	14-10- 4	16- 0- 1	17- 1-10	18- 3- 6	19- 5- 3	20- 7- 0	21- 8- 8	22-10- 5	29
12- 8- 5	13-10- 3	15- 0- 2	16- 2- 0	17- 3-10	18- 5- 8	19- 7- 7	20- 9- 5	21-11- 3	23- 1- 2	30
12-10- 0	14- 0- 0	15- 2- 0	16- 4- 0	17- 6- 0	18- 8- 0	19-10- 0	21- 0- 0	22- 2- 0	23- 4- 0	31
12-11- 8	14- 1-10	15- 3-11	16- 6- 1	17- 8- 3	18-10- 5	20- 0- 7	21- 2- 8	22- 4-10	23- 7- 0	32
13- 1- 5	14- 3- 8	15- 6- 0	16- 8- 4	17-10- 8	19- 0-11	20- 3- 3	21- 5- 7	22- 7-10	23-10- 2	33
13- 3- 3	14- 5- 8	15- 8- 2	16-10- 8	18- 1- 2	19- 3- 7	20- 6- 1	21- 8- 7	22-11- 0	24- 1- 6	34
13- 5- 2	14- 7-10	15-10- 5	17- 1- 1	18- 3- 9	19- 6- 5	20- 9- 0	21-11- 8	23- 2- 4	24- 5- 0	35
13- 7- 2	14-10- 0	16- 0-10	17- 3- 8	18- 6- 6	19- 9- 4	21- 0- 2	22- 3- 0	23- 5-10	24- 8- 8	36

OF THIS TABLE.

twelfths, as your span requires. Then rafter lengths given for every degree accordingly. Thus a roof pitched at 31° for a span of 6 *feet* is shown to 7 *inches*, and for a span of 6 *twelfths* (or ½") it has a rafter length of 7 *twelfths*. full, 7 feet 7 inches and 7 twelfths.

HIPS AND VALLEYS FOR ROOFS OF 12° TO 36° PITCH

Span of Rafter.										Pitch of roof in degrees.
11	12	13	14	15	16	17	18	19	20	
15- 8- 9	17- 1-11	18- 7- 1	20- 0- 3	21- 5- 5	22-10- 7	24- 3- 9	25- 8-11	27- 2- 1	28- 7- 3	12
15- 9- 2	17- 2- 4	18- 7- 6	20- 0- 9	21- 5-11	22-11- 2	24- 4- 4	25- 9- 6	27- 2- 8	28- 7-11	13
15- 9- 7	17- 2- 9	18- 8- 1	20- 1- 3	21- 6- 6	22-11- 9	24- 5- 0	25-10- 3	27- 3- 5	28- 8- 8	14
15-10- 0	17- 3- 3	18- 8- 7	20- 1-10	21- 7- 1	23- 0- 4	24- 5- 8	25-10-11	27- 4- 2	28- 9- 5	15
15-10- 6	17- 3-10	18- 9- 1	20- 2- 5	21- 7- 9	23- 1- 1	24- 6- 5	25-11- 8	27- 5- 0	28-10- 4	16
15-11- 0	17- 4- 4	18- 9- 9	20- 3- 1	21- 8- 5	23- 1-10	24- 7- 2	26- 0- 6	27- 5-11	28-11- 3	17
15-11- 7	17- 4-11	18-10- 4	20- 3- 9	21- 9- 2	23- 2- 7	24- 8- 0	26- 1- 5	27- 6-10	29- 0- 3	18
16- 0- 2	17- 5- 9	18-11- 1	20- 4- 6	21-10- 0	23- 3- 5	24- 8-11	26- 2- 5	27- 7-10	29- 1- 4	19
16- 0- 9	17- 6- 3	18-11-10	20- 5- 4	21-10-10	23- 4- 5	24- 9-11	26- 3- 5	27- 8-11	29- 2- 6	20
16- 1- 5	17- 7- 2	19- 0- 7	20- 6- 2	21- 1- 9	23- 5- 4	24-10-10	26- 4- 6	27-10- 1	29- 3- 8	21
16- 2- 2	17- 7-10	19- 1- 5	20- 7- 1	22- 0- 9	23- 6- 5	25- 0- 0	26- 5- 8	27-11- 4	29- 5- 0	22
16- 2-11	17- 8- 8	19- 2- 4	20- 8- 1	22- 1- 9	23- 7- 6	25- 1- 3	26- 6-11	28- 0- 8	29- 6- 5	23
16- 3- 8	17- 9- 6	19- 3- 4	20- 9- 1	22- 2-11	23- 8- 8	25- 2- 6	26- 8- 3	28- 2- 1	29- 7-10	24
16- 4- 7	17-10- 5	19- 4- 4	20-10- 1	22- 4- 0	23- 9-11	25- 3- 9	26- 9- 8	28- 3- 6	29- 9- 5	25
16- 5- 6	17-11- 5	19- 5- 4	20-11- 4	22- 5- 3	23-11- 3	25- 5- 2	26-11- 2	28- 5- 1	29-11- 0	26
16- 6- 5	18- 0- 6	19- 6- 6	21- 0- 6	22- 6- 7	24- 0- 7	25- 6- 8	27- 0- 8	28- 6- 9	30- 0- 9	27
16- 7- 6	18- 1- 7	19- 7- 9	21- 1-11	22- 8- 0	24- 2- 2	25- 8- 3	27- 2- 5	28- 8- 7	30- 2- 8	28
16- 8- 6	18- 2- 9	19- 8-11	21- 3- 2	22- 9- 5	24- 3- 8	25- 9-10	27- 4- 1	28-10- 4	30- 4- 7	29
16- 9- 8	18- 4- 0	19-10- 4	21- 4- 8	22-11- 0	24- 5- 4	25-11- 8	27- 6- 0	29- 0- 4	30- 6- 8	30
16-10-10	18- 5- 3	19-11- 8	21- 6- 2	23- 0- 7	24- 7- 0	26- 1- 6	27- 7-11	29- 2- 4	30- 8- 9	31
17- 0- 1	18- 6- 8	20- 1- 2	21- 7- 9	23- 2- 4	24- 8-10	26- 3- 5	27-10- 0	29- 4- 6	30-11- 1	32
17- 1- 5	18- 8- 1	20- 2- 9	21- 9- 5	23- 4- 1	24-10- 9	26- 5- 5	28- 0- 2	29- 6-10	31- 1- 6	33
17- 2-10	18- 9- 8	20- 4- 5	21-11- 3	23- 6- 0	25- 0-10	26- 7- 8	28- 2- 5	29- 9- 3	31- 4- 1	34
17- 4- 4	18-11- 3	20- 6- 2	22- 1- 1	23- 8- 1	25- 3- 0	26- 9-11	28- 4-10	29-11-10	31- 6- 9	35
17- 5-10	19- 0-11	20- 8- 0	22- 3- 1	23-10- 2	25- 5- 3	27- 0- 4	28- 7- 5	30- 2- 6	31- 9- 7	36

OF THIS TABLE.

the rafter pattern, in feet, in inches, or in twelfths, as your span requires. are also to be read in feet, in inches, or in twelfths accordingly. length of 9 *feet* 2 *inches*, for a span of 6 *inches* has a hip length of 9 *inches* for the 30° pitch when the rafter spans 6′ 6½″, hip and valley length will be

DEGREE ROOFING TABLE, GIVING LENGTH OF

Pitch of roof in degrees.	Span of Rafter. 1	2	3	4	5	6	7	8	9	10
37	1- 3- 0	2- 6- 1	3- 9- 1	5- 0- 1	6- 3- 2	7- 6- 2	8- 9- 2	10- 0- 3	11- 3- 3	12- 6- 3
38	1- 3- 3	2- 6- 5	3- 9- 8	5- 0-11	6- 4- 2	7- 7- 4	8-10- 7	10- 1-10	11- 5- 1	12- 8- 3
39	1- 3- 5	2- 6-11	3-10- 4	5- 1- 9	6- 5- 2	7- 8- 8	9- 0- 1	10- 3- 6	11- 7- 0	12-10- 5
40	1- 3- 8	2- 7- 4	3-11- 0	5- 2- 8	6- 6- 4	7-10- 0	9- 1- 8	10- 5- 4	11- 9- 0	13- 0- 8
41	1- 3-11	2- 7-10	3-11- 8	5- 3- 7	6- 7- 6	7-11- 5	9- 3- 4	10- 7- 2	11-11- 1	13- 3- 0
42	1- 4- 2	2- 8- 4	4- 0- 5	5- 4- 7	6- 8- 9	8- 0-11	9- 5- 0	10- 9- 2	12- 1- 4	13- 5- 6
43	1- 4- 5	2- 8-10	4- 1- 3	5- 5- 8	6-10- 0	8- 2- 5	9- 6-10	10-11- 3	12- 3- 8	13- 8- 1
44	1- 4- 8	2- 9- 4	4- 2- 1	5- 6- 9	6-11-5	8- 4- 1	9- 8- 9	11- 1- 5	12- 6- 2	13-10-10
45	1- 5- 0	2- 9-11	4- 2-11	5- 7-11	7- 0-10	8- 5-10	9-10-10	11- 3- 9	12- 8- 9	14- 1- 8
46	1- 5- 3	2-10- 7	4- 3- 9	5- 9- 1	7- 2- 5	8- 7- 8	10- 0-11	11- 6- 2	12-11- 6	14- 4- 9
47	1- 5- 7	2-11- 2	4- 4- 9	5-10- 5	7- 4- 0	8- 9- 7	10- 3- 2	11- 8- 9	13- 2- 4	14- 7-11
48	1- 5-11	2-11-10	4- 5-10	5-11- 9	7- 5- 8	8-11- 7	10- 5- 6	11-11- 6	13- 5- 5	14-11- 4
49	1- 6- 4	3- 0- 7	4- 6-11	6- 1- 2	7- 7- 5	9- 1- 9	10- 8- 0	12- 2- 4	13- 8- 7	15- 2-11
50	1- 6- 8	3- 1- 4	4- 8- 0	6- 2- 8	7- 9- 4	9- 4- 0	10-10- 8	12- 5- 4	14- 0- 0	15- 6- 8
51	1- 7- 1	3- 2- 2	4- 9- 2	6- 4- 3	7-11- 4	9- 6- 5	11- 1- 6	12- 8- 7	14- 3- 7	15-10- 8
52	1- 7- 6	3- 3- 0	4-10- 6	6- 6- 0	8- 1- 5	9- 8-11	11- 4- 5	12-11-11	14- 7- 5	16- 2-11
53	1- 7-11	3- 3-11	4-11-10	6- 7- 9	8- 3- 8	9-11- 8	11- 7- 7	13- 3- 6	14-11- 5	16- 7- 5
54	1- 8- 5	3- 4-10	5- 1- 3	6- 9- 8	8- 6- 1	10- 2- 6	11-10-11	13- 7- 4	15- 3- 9	17- 0- 2
55	1- 8-11	3- 5-10	5- 2- 9	6-11- 8	8- 8- 7	10- 5- 6	12- 2- 5	13-11- 5	15- 8- 4	17- 5- 3
56	1- 9- 6	3- 6-11	5- 4- 5	7- 1-10	8-11- 4	10- 8- 9	12- 6- 3	14- 3- 8	16- 1- 2	17-10- 7
57	1-10- 0	3- 8- 1	5- 6- 1	7- 4- 2	9- 2- 2	11- 0- 2	12-10- 3	14- 8- 3	16- 6- 4	18- 4- 4
58	1-10- 8	3- 9- 3	5- 7-11	7- 6- 7	9- 5- 3	11- 3-10	13- 2- 6	15- 1- 2	16-11-10	18-10- 5
59	1-11- 4	3-10- 7	5- 9-11	7- 9- 2	9- 8- 6	11- 7- 9	13- 7- 1	15- 6- 5	17- 5- 8	19- 5- 0
60	2- 0- 0	4- 0- 0	6- 0- 0	8- 0- 0	10- 0- 0	12- 0- 0	14- 0- 0	16- 0- 0	18- 0- 0	20- 0- 0
61	2- 0- 9	4- 1- 6	6- 2- 3	8- 3- 0	10- 3- 9	12- 4- 6	14- 5- 3	16- 6- 0	18- 6- 9	20- 7- 6

EXAMPLE SHOWING USE

Read the rafter span found at head of this table in feet, in inches, or in of pitch in the table are to be read as feet, as inches, or as twelfths a rafter length of 9 *feet* 4 *inches*, for a span of 6 *inches* it has a rafter length $\frac{3}{4}$". Then a rafter of 50° pitch that is to span 6' 6$\frac{1}{2}$" is seen to have a rafter

DEGREE ROOFING TABLE, GIVING LENGTHS OF

Pitch of roof in degrees.	Span of Rafter. 1	2	3	4	5	6	7	8	9	10
37	1- 7- 3	3- 2- 5	4- 9- 8	6- 4-11	8- 0- 2	9- 7- 5	11- 2- 7	12- 9-10	14- 5- 1	16- 0- 4
38	1- 7- 5	3- 2- 9	4-10- 2	6- 5- 7	8- 0-11	9- 8- 4	11- 3- 9	12-11- 1	14- 6- 6	16- 1-11
39	1- 7- 7	3- 3- 1	4-10- 8	6- 6- 3	8- 1- 9	9- 9- 4	11- 4-11	13- 0- 5	14- 8- 0	16- 3- 7
40	1- 7- 9	3- 3- 6	4-11- 2	6- 6-11	8- 2- 8	9-10- 5	11- 6- 2	13- 1-10	14- 9- 7	16- 5- 4
41	1- 7-11	3- 3-10	4-11- 9	6- 7- 8	8- 3- 7	9-11- 6	11- 7- 5	13- 3- 5	14-11- 4	16- 7- 3
42	1- 8- 1	3- 4- 3	5- 0- 4	6- 8- 6	8- 4- 7	10- 0- 8	11- 8-10	13- 4-11	15- 1- 1	16- 9- 2
43	1- 8- 4	3- 4- 8	5- 1- 0	6- 9- 4	8- 5- 8	10- 2- 0	11-10- 4	13- 6- 8	15- 2-11	16-11- 3
44	1- 8- 7	3- 5- 1	5- 1- 8	6-10- 2	8- 6- 9	10- 3- 4	11-11-10	13- 8- 5	15- 4-11	17- 1- 6
45	1- 8- 9	3- 5- 7	5- 2- 4	6-11- 2	8- 7-11	10- 4- 8	12- 1- 6	13-10- 3	15- 7- 1	17- 3-10
46	1- 9- 0	3- 6- 1	5- 3- 1	7- 0- 2	8- 9- 2	10- 6- 2	12- 3- 3	14- 0- 3	15- 9- 4	17- 6- 4
47	1- 9- 4	3- 6- 7	5- 3-11	7- 1- 2	8-10- 6	10- 7- 9	12- 5- 1	14- 2- 5	15-11- 8	17- 9- 0
48	1- 9- 7	3- 7- 2	5- 4- 9	7- 2- 4	8-11-11	10- 9- 6	12- 7- 1	14- 4- 8	16- 6- 2	17-11- 9
49	1- 9-11	3- 7- 9	5- 5- 8	7- 3- 6	9- 1- 5	10-11- 3	12- 9- 2	14- 7- 0	16- 4-11	18- 2- 9
50	1-10- 2	3- 8- 5	5- 6- 7	7- 4- 9	9- 3- 0	11- 1- 2	12-11- 4	14- 9- 7	16- 7- 9	18- 5-11
51	1-10- 6	3- 9- 1	5- 7- 7	7- 6- 1	9- 4- 8	11- 3- 2	13- 1- 8	15- 0- 3	16-10- 9	18- 9- 4
52	1-10-11	3- 9- 9	5- 8- 8	7- 7- 7	9- 6- 5	11- 5- 4	13- 4- 3	15- 3- 1	17- 2- 0	19- 0-11
53	1-11- 3	3-10- 7	5- 9-10	7- 9- 1	9- 8- 4	11- 7- 8	13- 6-11	15- 6- 2	17- 5- 5	19- 4- 9
54	1-11- 8	3-11- 4	5-11- 1	7-10- 9	9-10- 5	11-10- 1	13- 9- 9	15- 9- 5	17- 9- 2	19- 8-10
55	2- 0- 2	4- 0- 3	6- 0- 4	8- 0- 6	10- 0- 7	12- 0- 9	14- 0-10	16- 0-11	18- 1- 1	20- 1- 2
56	2- 0- 7	4- 1- 2	6- 1- 9	8- 2- 4	10- 2-11	12- 3- 6	14- 4- 1	16- 4- 8	18- 5- 3	20- 5-10
57	2- 1- 1	4- 2- 2	6- 3- 3	8- 4- 4	10- 5- 5	12- 6- 6	14- 7- 8	16- 8- 9	18- 9-10	20-10-11
58	2- 1- 8	4- 3- 3	6- 4-11	8- 6- 6	10- 8- 2	12- 9- 9	14-11- 5	17- 1- 0	19- 2- 8	21- 4- 3
59	2- 2- 2	4- 4- 5	6- 6- 8	8- 8-10	10-11- 0	13- 1- 3	15- 3- 5	17- 5- 8	19- 7-11	21-10- 1
60	2- 2-10	4- 5- 8	6- 8- 6	8-11- 4	11- 2- 2	13- 5- 0	15- 7-10	17-10- 8	20- 1- 6	22- 4- 4
61	2- 3- 6	4- 7- 0	6-10- 6	9- 2-10	11- 5- 6	13- 9- 1	16- 0- 7	18- 4- 1	20- 7- 7	22-11- 1

EXAMPLE SHOWING USE

At head of this table read the same rafter span that has already been used hip and valley lengths given for every degree of roof pitch in the table roof pitched at 43°, for a rafter span of 6 *feet*, has a hip and valley length of 2 *twelfths*, and for a half-inch span has a rafter length of 10 *twelfths*. Then 11-1-0, or, in full, 11 feet and 1 inch.

RAFTERS FOR ROOFS OF 37° TO 61° PITCH

Span of Rafter.										Pitch of roof in degrees.
11	12	13	14	15	16	17	18	19	20	
13- 9- 3	15- 0- 4	16- 3- 4	17- 6- 4	18- 9- 5	20- 0- 5	21- 3- 5	22- 6- 6	23- 9- 6	25- 0- 6	37
13-11- 6	15- 2- 9	16- 6- 0	17- 9- 2	19- 0- 5	20- 3- 8	21- 6-11	22-10- 1	24- 1- 4	25- 4- 7	38
14- 1-10	15- 5- 4	16- 8- 9	18- 0- 2	19- 3- 7	20- 7- 1	21-10- 6	23- 1-11	24- 5- 5	25- 8-10	39
14- 4- 4	15- 8- 0	16-11- 8	18- 3- 4	19- 7- 0	20-10- 8	22- 2- 4	23- 6- 0	24- 9- 8	26- 1- 4	40
14- 6-11	15-10-10	17- 2- 8	18- 6- 7	19-10- 6	21- 2- 5	22- 6- 4	23-10- 2	25- 2- 1	26- 6- 0	41
14- 9- 8	16- 1-10	17- 5-11	18-10- 1	20- 2- 3	21- 6- 4	22-10- 6	24- 2- 8	25- 6-10	26-10-11	42
15- 0- 6	16- 4-11	17- 9- 4	19- 1- 9	20- 6- 1	21-10- 6	23- 2-11	24- 7- 4	25-11- 9	27- 4- 2	43
15- 3- 6	16- 8- 2	18- 0-10	19- 5- 7	20-10- 3	22- 2-11	23- 7- 7	25- 0- 3	26- 4-11	27- 9- 8	44
15- 6- 8	16-11- 8	18- 4- 7	19- 9- 7	21- 2- 7	22- 7- 6	24- 0- 6	25- 5- 6	26-10- 5	28- 3- 5	45
15-10- 0	17- 3- 4	18- 8- 7	20- 1-10	21- 7- 2	23- 0- 5	24- 5- 8	25-10-11	27- 4- 3	28- 9- 6	46
16- 1- 7	17- 7- 2	19- 0- 9	20- 6- 4	21-11-11	23- 5- 6	24-11- 2	26- 4- 9	27-10- 4	29- 3-11	47
16- 5- 3	17-11- 2	19- 5- 2	20-11- 1	22- 5- 0	23-10-11	25- 4-11	26-10-10	28- 4- 9	29-10- 8	48
16- 9- 2	18- 3- 6	19- 9- 9	21- 4- 1	22-10- 4	24- 4- 8	25-10-11	27- 5- 3	28-11- 6	30- 5-10	49
17- 1- 4	18- 8- 0	20- 2- 8	21- 9- 4	23- 4- 0	24-10- 8	26- 5- 4	28- 0- 0	29- 6- 8	31- 1- 5	50
17- 5- 9	19- 0-10	20- 7-11	22- 2-11	23-10- 0	25- 5- 1	27- 0- 2	28- 7- 3	30- 2- 4	31- 9- 4	51
17-10- 5	19- 5-11	21- 1- 5	22- 8-11	24- 4- 4	25-11-10	27- 7- 4	29- 2-10	30-10- 4	32- 5-10	52
18- 3- 4	19-11- 3	21- 7- 3	23- 3- 2	24-11- 1	26- 5- 0	28- 3- 0	29-10-11	31- 6-10	33- 2- 9	53
18- 8- 7	20- 5- 0	22- 1- 5	23- 9-10	25- 6- 3	27- 2- 8	28-11- 1	30- 7- 6	32- 3-11	34- 0- 4	54
19- 2- 2	20-11- 1	22- 8- 0	24- 4-11	26- 1-10	27-10- 9	29- 7- 8	31- 4- 7	33- 1- 6	34-10- 5	55
19- 8- 1	21- 5- 6	23- 3- 0	25- 0- 5	26- 9-11	28- 7- 4	30- 4-10	32- 2- 3	33-11- 9	35- 9- 2	56
20- 2- 5	22- 0- 5	23-10- 5	25- 8- 6	27- 6- 6	29- 4- 7	31- 2- 7	33- 0- 7	34-10- 8	36- 8- 8	57
20- 9- 1	22- 7- 9	24- 6- 5	26- 5- 0	28- 3- 8	30- 2- 4	32- 1- 0	33-11- 7	35-10- 3	37- 8-11	58
21- 4- 3	23- 3- 7	25- 2-11	27- 2- 2	29- 1- 6	31- 0- 9	33- 0- 1	34-11- 4	36-10- 8	38-10- 0	59
22- 0- 0	24- 0- 0	26- 0- 0	28- 0- 0	30- 0- 0	32- 0- 0	34- 0- 0	36- 0- 0	38- 0- 0	40- 0- 0	60
22- 8- 3	24- 9- 0	26- 9- 9	28-10- 6	30-11- 3	33- 0- 0	35- 0- 9	37- 1- 6	39- 2- 3	41- 3- 0	61

OF THIS TABLE.

twelfths, as your span requires. Then rafter lengths given for every degree accordingly. Thus a roof pitched at 50°, for a span of 6 *feet* is shown to have of 9 *inches* and 4 *twelfths*, and for a half-inch span will have a rafter length of length of 10–2–1, or, in full, 10 feet 2 inches and 1 twelfth.

HIPS AND VALLEYS FOR ROOFS OF 37° TO 61° PITCH

Span of Rafter.										Pitch of roof in degrees.
11	12	13	14	15	16	17	18	19	20	
17- 7- 6	19- 2- 9	20-10- 0	22- 5- 3	24- 0- 5	25- 7- 8	27- 2-11	28-10- 2	30- 5- 4	32- 0- 7	37
17- 9- 3	19- 4- 8	21- 0- 1	22- 7- 5	24- 2-10	25-10- 3	27- 5- 7	29- 1- 0	30- 8- 5	32- 3- 9	38
17-11- 1	19- 6- 8	21- 2- 3	22- 9- 9	24- 5- 4	26- 0-11	27- 8- 5	29- 4- 0	30-11- 7	32- 7- 1	39
18- 1- 1	19- 8-10	21- 4- 6	23- 0- 3	24- 8- 0	26- 3- 9	27-11- 5	29- 7- 2	31- 2-11	32-10- 8	40
18- 3- 2	19-11- 1	21- 7- 0	23- 2-11	24-10-10	26- 6- 9	28- 2- 8	29-10- 7	31- 6- 6	33- 2- 5	41
18- 5- 2	20- 1- 5	21- 9- 6	23- 5- 8	25- 1- 9	26- 9-11	28- 6- 0	30- 2- 2	31-10- 3	33- 6- 4	42
18- 7- 7	20- 3-11	22- 0- 2	23- 8- 7	25- 4-11	27- 1- 3	28- 9- 7	30- 5- 1	32- 2- 3	33-10- 7	43
18-10- 1	20- 6- 7	22- 3- 2	23-11- 8	25- 8- 3	27- 4-10	29- 1- 4	30- 9-11	32- 6- 5	34- 3- 0	44
19- 0- 8	20- 9- 5	22- 6- 2	24- 3- 0	25-11- 9	27- 8- 7	29- 5- 4	31- 2- 2	32-10-11	34- 7- 8	45
19- 3- 4	21- 0- 5	22- 9- 5	24- 6- 6	26- 3- 6	28- 0- 6	29- 9- 7	31- 6- 7	33- 3- 8	35- 0- 8	46
19- 6- 3	21- 3- 7	23- 0-11	24-10- 2	26- 7- 6	28- 4- 9	30- 2- 1	31-11- 4	33- 8- 8	35- 5-11	47
19- 9- 4	21- 6-11	23- 6- 6	25- 2- 1	26-11- 8	28- 9- 3	30- 6-10	32- 4- 5	34- 2- 0	35-11- 7	48
20- 0- 8	21-10- 6	23- 8- 5	25- 6- 3	27- 4- 2	29- 2- 0	30-11-11	32- 9- 9	34- 7- 8	36- 5- 6	49
20- 4- 2	22- 2- 4	24- 0- 6	25-10- 8	27- 8-11	29- 7- 1	31- 5- 3	33- 3- 6	35- 1- 8	36-11-10	50
20- 7-10	22- 6- 4	24- 4- 4	26- 3- 5	28- 1-11	30- 0- 6	31-11- 0	33- 9- 6	35- 8- 1	37- 6- 7	51
20-11- 9	22-10- 8	24- 9- 7	26- 8- 5	28- 7- 4	30- 6- 3	32- 5- 1	34- 4- 0	36- 2-11	38- 1- 9	52
21- 4- 0	23- 3- 3	25- 2- 6	27- 1-10	29- 1- 1	31- 0- 4	32-11- 8	34-10-11	36-10- 2	38- 9- 5	53
21- 8- 6	23- 8- 2	25- 7-10	27- 7- 6	29- 7- 3	31- 6-11	33- 6- 7	35- 6- 3	37- 5-11	39- 5- 8	54
22- 1- 4	24- 1- 5	26- 1- 7	28- 1- 8	30- 1- 9	32- 1-11	34- 2- 0	36- 2- 2	38- 2- 3	40- 2- 5	55
22- 6- 5	24- 7- 1	26- 7- 8	28- 8- 3	30- 8-10	32- 9- 5	34-10- 0	36-10- 7	38-11- 2	40-11- 9	56
23- 0- 0	25- 1- 1	27- 2- 2	29- 3- 3	31- 4- 4	33- 5- 5	35- 6- 6	37- 7- 7	39- 8- 8	41- 9- 9	57
23- 5-11	25- 7- 6	27- 9- 2	29-10-10	32- 0- 5	34- 2- 1	36- 3- 8	38- 5- 4	40- 6-11	42- 8- 7	58
24- 0- 3	26- 2- 6	28- 4- 8	30- 6-11	32- 9- 2	34-11- 4	37- 1- 6	39- 3- 9	41- 5-11	43- 8- 2	59
24- 7- 2	26-10- 0	29- 0-10	31- 3- 8	33- 6- 6	35- 9- 4	38- 0- 2	40- 3- 0	42- 5-10	44- 8- 8	60
25- 2- 7	27- 6- 1	29- 9- 7	31- 1- 1	34- 4- 7	36- 8- 2	38-11- 8	41- 3- 2	43- 6- 8	45-10- 2	61

OF THIS TABLE.

for the rafter, in feet, in inches, or in twelfths, as your span requires. Then are also to be read in feet, in inches, or in twelfths accordingly. Thus a 10 *feet* 2 *inches*, for a span of 6 *inches* it has a hip length of 10 *inches* and for the 43° pitch, when the rafter spans 6′ 6½″, hip and valley length will be